

EXPERT REPORT OF DR. RON SASS

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I have been asked to provide expert testimony on behalf of the Plaintiff regarding certain aspects of the San Jacinto River Waste Pit and related litigation.

I will present evidence supporting the contention that the fishermen and other persons suffer damages as a result of the generation, transport, placement, storage, and possibly other activities with regard to waste materials in that location at the San Jacinto River.

My testimony will encompass the chemical, physical, hydrological and other properties of a class of toxic compounds commonly called dioxins. My observations and opinions in this matter are based on my education and experience, as well as information reported by others and discussed below.

I may supplement this report with additional information and opinions, particularly if additional information should be made available for my review.

I. QUALIFICATIONS, AREAS OF EXPERTISE, AND COMPENSATION

I am the Harry C. and Olga Keith Wiess Professor Emeritus of Natural Sciences in the Departments of Chemistry and Ecology and Evolutionary Biology at Rice University in Houston, Texas. I am also a Fellow in Energy and Climate Change of the James A. Baker Institute of Public Policy. My business address is 1834 Norfolk Street, Houston, Texas 77098.

I received a B.A. degree in chemistry and mathematics from Augustana College in Rock Island Illinois and a Ph.D. in Physical Chemistry from the University of Southern California. Upon receiving my Ph.D., I was awarded a post-doctoral fellowship at the Brookhaven National Laboratory in New York before accepting a position of assistant professor at Rice University in 1958. Since that time I have been a member of the faculty of the Chemistry, Biology, and Ecology and Evolutionary Biology Departments. I was chair of the Biology and then the Ecology and Evolutionary Biology Department at Rice University from 1981 to 2005 when I took Emeritus status. I conducted research as Co-Director of the Wetland Center for Biogeochemical Research at Rice University from 1988 to 2006. I have had

additional experiences as a Guggenheim Fellow of theoretical chemistry at Cambridge University and as a National Research Fellow with NASA in Virginia, Alaska, and Canada.

My career at Rice University has covered a span of over fifty years, conducting an active research program, teaching and serving the local, national and international scientific communities.

My research has covered a variety of subjects working with many undergraduates, graduate students and post-doctoral fellows. I have published over 165 papers in reviewed journals and have acted as editor and author in several books. I have taught a variety of graduate and undergraduate courses in chemistry (general chemistry, physical chemistry, quantum chemistry, x-ray diffraction), biology (introductory biology, general physiology, biophysical chemistry) and ecology (earth systems, environmental science, climate change dynamics, and environmental literature). My service work includes being a member of most of the faculty committees at Rice, Co-Director of the Center for Education (teacher training), Master of Hanszen Residential College. Nationally, I have been Chair of the Chemistry Examination for the SAT's, Chair of the international rice research team of the International Global Atmospheric Chemistry program, a member of the American Chemical Society, American Crystallographic Society and the American Geophysical Union. As a charter member and an author for the Intergovernmental Panel on Climate Change I shared in the 2007 Nobel Peace Prize awarded to the IPPC. I currently serve as a member of the Board of Trustees of the Galveston Bay Foundation and the Nature Conservancy. As a Fellow of the Baker Institute I participate in workshops, symposia and conferences on questions of science policy. I have recently published several policy papers dealing with environmental issues in Texas through the Baker Institute.

While earning my B.A. degree at Augustana College I worked full time as a chemist for the Corp of Engineers developing nuclear chemical analytical methods and inventing an all-weather grease for the US Army. My graduate school research was

in X-ray diffraction studies of the structures of certain chemical compounds. At Brookhaven National Laboratories, I conducted thermal neutron scattering experiments to determine nuclear spin orientations of anti-ferromagnetic materials and characterize the crystal and molecular structure of hydrogen bonding materials. During my fifty years at Rice University I conducted experiments in x-ray crystallography, Fourier transfer filtering analysis of electron micrographic images, physiology of cardiac and skeletal muscle, and calcification studies on a variety of mollusk species. The final twenty years of my active research career was the Co-Director of the Wetlands Research Laboratory at Rice and active in research in the role of a biogeochemist studying the processes characterizing wetland-generated methane as a greenhouse gas and the general properties of greenhouse gases. I am now a Professor Emeritus of Chemistry and Ecology and Evolutionary Biology at Rice University in Houston, Texas, but an active Fellow of the James A. Baker Institute for Public Policy and a faculty member of the School of Continuing Education at Rice University.

My *Curriculum Vitae* is attached and includes a list of my publications and additional details regarding my qualifications, education, and experience. I am being compensated at a rate of \$ 200 per hour for time spent preparing my expert report and for any depositions or testimony.

II. INFORMATION CONSIDERED

I have considered all of the articles provided herein and other papers and documents cited in my opinions below.

III. INTRODUCTION

The San Jacinto River Waste Pits (SJRW) site is nominally located in the city of Channelview, even though it actually sits in the middle of the San Jacinto River as it flows under the Interstate Highway 10 bridge. The site occupies a 20-acre tract of land currently owned by Virgil C. McGinnis. The pits consist of three surface impoundments that were constructed between October 1964 and February 1973

(SJRW 31). No information is available describing the construction of the impoundments. Because of subsidence in the area, two of the pits are now submerged under approximately a foot of water. The third pit is on somewhat higher ground and is separated from the submerged pit by a 6-foot-high berm (SJRW 31).

Beginning soon after construction, the pits were utilized from the mid-1960's through the middle of the 1970's by the Champion Paper Co., located in Pasadena TX, for the disposal of paper mill wastes. Barges loaded with waste sludge were regularly observed discharging into the pits on the site (SJRW 31).

The modern era of large pulp and paper mills in Texas began in the late 1930s, when the Champion Coated Paper Company of Ohio constructed its bleached-sulfate pulp mill on the Houston Ship Channel at Pasadena. Initially pulp from the mill was shipped to Ohio, where it was manufactured into fine printing papers. The Champion mill has since been expanded to include paper machines and in the late 1980s produced 750 tons of bleached coated and uncoated papers a day.

Since paper mill waste from the 1960's and 1970's is now known to have contained high levels of polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs), better known as dioxins, as a result of the chlorine bleaching process then in use, the waste pits contribute to the elevated levels of dioxins found in the San Jacinto River and Upper Galveston Bay (SJRW 31).

IV. CHEMICAL AND PHYSICAL PROPERTIES OF DIOXINS

Environmental fate modeling of dioxins requires knowledge of a number of fundamental physical and chemical parameters, such as water solubility, vapor pressure, Henry's law constant, octanol-water partition coefficient (K_{ow}), and organic carbon partition coefficient (K_{oc}). PCDDs are a class of high molecular weight, highly hydrophobic compounds. Although the class contains 8 homologues (congener groups) and 75 congeners, solubility values are available for only a handful of these congeners. PCDDs have very low water solubility, with solubility

decreasing with increasing chlorine substitutions. The water solubility of 2,3,7,8-TCDD ranges from 7.9×10^{-6} to 33.2×10^{-4} mg/L. Water solubility at 25°C for the congener groups have been estimated as follows: MCDD, 0.278–0.417 mg/L; DCDD, 3.75×10^{-3} – 1.67×10^{-2} mg/L; TrCDD, 4.75×10^{-3} – 8.41×10^{-3} ; TCDD, 7.9×10^{-6} to 6.3×10^{-4} mg/L; PeCDD, 1.18×10^{-4} mg/L; HxCDD, 4.42×10^{-6} mg/L; HpCDD, 2.4×10^{-6} – 1.9×10^{-3} mg/L; and OCDD, 0.1×10^{-9} – 7.4×10^{-8} mg/L (SJRW 56).

PCDDs generally exhibit very low vapor pressures, with the tendency of decreasing vapor pressure with increasing chlorine substitution. At 25 EC, the vapor pressure of 2,3,7,8-TCDD ranges from 7.4×10^{-10} to 3.4×10^{-5} mm Hg. Vapor pressures at 25 EC for the other congener groups have been estimated as follows: MCDD, 9.0×10^{-5} – 1.3×10^{-4} mm Hg; DCDD, 9.0×10^{-7} – 2.9×10^{-6} mm Hg; 6.46×10^{-8} – 7.5×10^{-7} ; TCDD, 7.4×10^{-10} – 4.0×10^{-3} mm Hg; PeCDD, 6.6×10^{-10} mm Hg; HxCDD, 3.8×10^{-11} mm Hg; HpCDD, 5.6×10^{-12} – 7.4×10^{-8} mm Hg; and OCDD, 8.25×10^{-13} – 1.68×10^{-12} mm Hg (SJRW 24). CDDs can be found in both the vapor and particle-bound phases with the low vapor pressure of OCDD resulting in its enrichment in the particulate phase in the atmosphere. When this particulate matter is deposited on water, OCDD-enriched sediments will result. The less chlorinated PCDD congeners (TCDD and PeCDD) occur in greater proportion in the vapor and dissolved phases of air and rain, whereas the more chlorinated congeners (HpCDD and OCDD) are associated with the particulate-bound phases. Data from one study of PCDDs in the ambient atmosphere of Bloomington, IN, found that vapor-to-particle ratios for individual PCDDs ranged from 0.01 to 30 and were dependent on the ambient temperature and the compound's vapor pressure. Since the less-chlorinated PCDDs have higher vapor pressures, they are found to a greater extent in the vapor phase (SJRW 24)). As air moves, photodegradation of the vapor-phase PCDDs occurs and they are lost more readily than the particulate-bound PCDDs. Vapor-phase PCDDs are not likely to be removed from the atmosphere by wet or dry deposition, although this is a primary removal process for particulate-bound PCDDs. Wet or dry deposition could result in greater concentrations of the more chlorinated PCDDs reaching soil or water surfaces and eventually sediment. All PCDDs are found to some extent in both the vapor phase and bound to particulates. At warmer temperatures (28°C), PCDDs, particularly the MCDDs, DCDDs, TrCDDs, and TCDDs

will have a greater tendency to exist in the vapor phase. At cooler temperatures (16–20°C and <3°C), all PCDDs will have less propensity to exist in the vapor phase and greater propensity to adsorb to particulates. At a constant temperature, there is a positive relationship between increasing numbers of chlorine atoms on the molecule and decreased propensity to exist in the vapor phase relative to particulate adsorption (SJRW 24).

V. DISPOSAL OF DIOXINS

The 1994 estimates on the degree of TCDD contamination in the environment indicated that approximately 500,000 tons of soil and sediment in the United States were contaminated with 2,3,7,8-TCDD. The development of treatment technologies for PCDD-contaminated soils and wastes needed to address unique problems associated with PCDDs: for example, they are insoluble in water, only slightly soluble in organic solvents, have a strong affinity for adsorption on organic matter, and are biologically and environmentally stable (SJRW 57). In order to meet the clean-up standards established for PCDDs, the treatment system must be capable of removing the PCDDs from the contaminated matrix. Several treatment or disposal methods for PCDDs and PCDD-contaminated materials have been investigated, including land disposal, thermal destruction, and chemical and biological degradation. Each of these methods has limitations regarding economics, technical feasibility, and acceptability (SJRW 57).

Land disposal of PCDD-containing wastes is currently prohibited (SJRW 56). The Toxic Substances Control Act (TSCA) regulates the use, disposal, and distribution in commerce of process wastewater treatment of sludge intended for land application from pulp and paper mills employing chlorine or PCDDs chlorine derivative-based bleaching processes (SJRW 56). Also, under the Marine Protection Research and Sanctuaries Act, ocean dumping of PCDD-containing wastes is prohibited except when only trace amounts are present (SJRW 56).

Thermal destruction technologies offer the most straightforward approach to treating or disposing of PCDD-contaminated materials because under the appropriate conditions the breakdown of the PCDDs is assured. The thermal

treatment technologies that are currently used to treat waste containing hazardous or toxic constituents and that have demonstrated potential use toward the treatment of PCDD-contaminated waste include rotary kiln incineration, liquid injection incineration, fluidized-bed incineration, advanced electric reactor (AER), infrared incineration, plasma arc pyrolysis incineration, supercritical water oxidation, and *in situ* vitrification. In addition to kiln incinerators, the technologies that have been field-tested for treating PCDD-contaminated media under EPA's Superfund Innovative Technology Evaluation (SITE) program include dechlorination, stabilization, and *in situ* vitrification (U.S. Congress 1991). Although some alternatives look promising and have been shown effective in the laboratory or in application to other pollutants, more development and testing is needed to demonstrate viability for large-scale treatment of PCDD contamination.

Incineration, involving the high-temperature oxidation of PCDD molecules, is the most extensively tested method for disposal of PCDDs. PCDDs such as TCDD, PeCDD, and HxCDD are classified by EPA as Principal Organic Hazardous Constituents (POHCs) and are required to be incinerated under conditions that achieve a destruction and removal efficiency of 99.99% (SJRWP 56). Incinerator operating conditions currently considered adequate for destruction of 2,3,7,8-TCDD and most other chlorinated organics require a temperature of at least 1,500–2,600 °F, with residence times of at least 30 minutes (although 1.5 hours is a more common residence time) to ensure complete destruction (SJRWP 56). Thermal destruction of PCDDs that are adsorbed on fly ash can be accomplished through the use of a rotary kiln furnace combined with a filter for the recycling of entrained fly ash and an activated carbon filter for adsorption of CDD traces transported in the gas phase. This method is capable of destroying 99.5% of PCDDs in fly ash, which is considered a high level of efficiency (SJRWP 56). EPA's Mobile Incineration System, a transportable rotary kiln system, was judged to be more than adequate for detoxifying PCDD-contaminated solids and liquids after it was performance-tested with a variety of uncontaminated soils and other solid wastes, and thus could be expected to accomplish a successful PCDD trial burn. The system, which has been

extensively modified for field use, consists of a rotary-kiln, a secondary combustion chamber, an air pollution control unit, and separate continuous stack-gas analysis capabilities. In 1977, the U.S. Air Force disposed of Agent Orange contaminated with 2,3,7,8-TCDD by high temperature incineration at sea. The high flame temperature reached 1,500 EC in the incinerator, and EPA determined a combustion efficiency of 99.9% for 2,3,7,8-TCDD (SJRWP 56).

Kiln incinerators have been used to treat a variety of containerized and noncontainerized solid and liquid wastes. Since the waste can be treated individually or simultaneously, the versatility of this technology has made it popular in the United States for disposing of hazardous waste. For the disposal of PCDD-containing waste, however, kiln incineration is more commonly practiced in Europe than in the United States (SJRWP 57). Although liquid injection incineration has been used for ocean-based incineration of Agent Orange, certain limitations must be considered before applying the technology to treating PCDD contamination. These limitations include the applicability of the technology only to combustible low-viscosity liquids and slurries that can be pumped; atomizing the waste prior to injection into the combustor; and the importance of particle size because burners are susceptible to clogging (SJRWP 57). Fluidized-bed combustion (FBC) systems have traditionally been used to treat the sludge produced by municipal waste treatment plants and waste generated from oil refineries, pulp and paper mills, and the pharmaceutical industry. The system consists of a vertical refractory-lined vessel that holds a perforated plate. A bed of granular material, usually sand, is placed on the perforated plate. The system uses forced hot air to fluidized the bed and cause a highly turbulent zone that ensures the mixing of the waste with bed particles and the combustion air. Combustion is facilitated by an overhead burner (SJRWP 57). The type and size of materials to be treated are critical because variations in gravity and density could be deleterious to the process (SJRWP 57). Modification of the traditional FBC system for treatment of chlorinated wastes continues to be investigated by researchers in the private sector. A modified system designed by Waste-Tech Services, Inc. uses a granular bed composed of a mixture of

combustion catalyst and limestone. The results of the trial burn for the Waste-Tech Services system which used chlorinated waste containing carbon tetrachloride, tetrachloroethane, p-dichlorobenzene and some PCDDs and PCDFs, showed no measurable amount of any of the chlorinated pollutants treated and no 2,3,7,8-TCDD in any of the samples tested (SJRW 57). *In situ* vitrification (ISV), which treats waste in place, solidifies all materials not volatilized or destroyed. Bench-scale testing of ISV on soils containing 10 ppb PCDDs showed destruction removal efficiency (DRE) values of 99.9999% (SJRW 57).

Since the early 1970s, several chemical methods have been investigated for the degradation of PCDDs. Treatment of PCDD-contaminated materials with alkali polyethylene glycolate (APEG) reagents at hazardous waste sites has been demonstrated to successfully destroy PCDDs in liquid wastes and to be viable even under difficult circumstances. This method involves the reaction of potassium hydroxide with polyethylene glycol to form an alkoxide that reacts with one of the chlorine atoms on the CDD to produce an ether and potassium chloride. Bioassays indicate that the by-products produced by treating 2,3,7,8-TCDD with APEG reagents do not bioaccumulate or bioconcentrate, do not cause mutagenicity, and are far less toxic than 2,3,7,8-TCDD. Cleavage of the ether linkages with the formation of halophenols may be achieved by treatment with strong acids or quaternary ammonium salts, but the dibenzodioxin nucleus is resistant to chemical attack. The dechlorination of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) was investigated using a modified alkali-metal hydroxide method. The destruction reagent, prepared by dissolving either potassium hydroxide or sodium hydroxide in 1,3-dimethyl-2-imidazolidinone (DMI) destroyed all components regardless of the difference in the number of chlorine atoms or isomers of PCDDs and PCDFs. The efficiency of the methods was evaluated under varying conditions; in the presence and absence of water, at 90 and 50 °C, for 0.5 and 5 hours. Although the degree of PCDD destruction (99.95–99.80%) was less than that for PCDFs (99.99–99.98%), overall, the investigators considered the DMI reagent to be more useful than the polyethylene glycols because of its stability

under strongly basic conditions and its efficiency in the presence of water (SJRWP 56).

Ruthenium tetroxide treatment can cause oxidative degradation of PCDDs. This method can be used for detoxification of glassware and artifacts, or for the periodic purging of industrial reactors to counteract the accumulation of PCDD residues. There is no available evidence on the nature of fragments formed during oxidation of the PCDDs; however, the related chlorophenols undergo extensive decomposition to yield chlorine ions and no significant levels of organic products. Other chemical methods of detoxification include exposure to ultraviolet light or gamma radiation, the use of ozone or special chloroiodide compounds, and the use of solvents or adsorbents to concentrate PCDDs into smaller volumes for final disposal by incineration (SJRWP 56).

A theoretical analysis of an *in situ* method for decontaminating soil by photodegradation was proposed in 1993. Up to 86% of TCDD in the soil can be degraded by this process (SJRWP 56). Because of its extremely low water solubility and volatility, TCDD is a very persistent soil contaminant. With the method, based on the physical properties that facilitate photolysis of TCDD by sunlight, an organic solvent mixture (2:1 w/w) of tetradecane and 1-butanol is applied to the contaminated soil (SJRWP 56). The controlling factors in TCDD photodegradation are desorption of the compound from the soil, the transport mechanism to the soil surface, and the availability of sunlight. As the solvents remove the tightly bound TCDD from the soil, convective upward movements of the compound are caused by the evaporation of the solvent. The effectiveness of the process also depends on a balance between the convective movement and sunlight availability for degradation (SJRWP 56). Modeling has identified and quantified the controlling factors governing the TCDD photodegradation process. Following the concentration variation of TCDD in the top 2 mm of soil through sunlight/night cycles over an exposure period of 15 days, the model showed that during the daytime of the first few days, there is little accumulation of TCDD as the losses due to photodegradation were almost equal to the convective flux in magnitude but with different signs.

Although the losses due to photodegradation drop to zero at night, the convective flux affected a build-up of TCDD. The losses due to photodegradation held steady while the convective movements decreased as evaporation slowed down. A balance between the build-up of TCDD concentration at night and the drop in concentration during the day did not occur until the eleventh day of exposure (SJRWP 56).

Hilarides, in 1994, investigated degradation of TCDD in the presence of surfactants. Their results indicated that radiolytic destruction of TCDD using γ radiation can be achieved. Greater than 92% of the TCDD was destroyed in soils amended with 100 ppb TCDD, 25% water, and 2% nonionic surfactant using ^{60}Co at high radiation doses (800 kGy or 80 Mrad). The use of ^{60}Co as a source avoids the temperature increases and power requirements of other sources of ionizing radiation such as an electron beam. It is also better suited for soil application because of its greater penetration depths (SJRWP 56).

Biotreatment systems that use microorganisms for degradation of refractory organopollutants, like PCDDs, are also being considered. *Phanerochaete chrysosporium*, a white rot fungus, has shown the ability to slowly degrade 2,3,7,8-TCDD in the laboratory. The ability of this fungus to metabolize 2,3,7,8-TCDD is thought to be related to its extracellular lignin degrading enzyme system (SJRWP 56).

VI. THE HISTORY OF DIOXINS

The history of dioxin is a story of sometimes devastating sickness inflicted on unaware workers in the chemical industry. For example, Monsanto Chemical Company first began the manufacture of polychlorbiphenyl in Anniston, Alabama using a process, we now know, that inevitably produces dioxin-like substances as well as a byproduct. And the first unwitting discovery that such materials create dangerous industrial hazards to chemical workers was made in the early 1930s when most of the workers in the Monsanto plant became sick (SJRWP 45).

Humans are not the only animals that are affected by dioxins. In 1957, an unidentified disease was killing millions of young chickens in the eastern and Midwestern U. S. The symptoms were excessive fluid in the heart sac and abdominal cavity. The cause was eventually traced to fatty acids that were added to the chicken's feed. Several years of hard investigative work finally led scientists to the root cause. They finally isolated one of the toxic materials involved and identified it by X-ray crystallography as 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin. The source of this dioxin in the fatty acid supplement was found to reside in the hide tanning industry. The first step in the tanning process was to apply large amounts of salt to the hides as a preservative, but in the past several decades the salt was supplanted by chlorinated phenols as a preservative, which we now know was contaminated during manufacture by dioxins and furans. As the fat was stripped from the hides, the chlorinated compounds, being lipophilic, ended up in the grease. This material was then saponified to produce fatty acids that were then purified by high temperature distillation. These procedures tended to dimerize the chlorinated phenols and to concentrate the resulting dioxin impurities in the fatty acid product that was then used as a supplement in chicken feed. By the 1970's the "chicken problem" was solved (SJRW 44).

Near Times Beach, Missouri, on May 26, 1971, 2,000 gallons of waste oil were sprayed on the soil of a horse arena to keep down the dust. Three days later the arena was littered with dead birds. The next day three horses and the ringmaster were sick. By June, 29 horses, 11 cats and 4 dogs had died. In August the six-year-old daughter of the arena owner was admitted to the hospital with a severe kidney disorder. Several other children and adults reported ailments. In August 1974, after the removal of a foot of soil, the arena could once again shelter healthy horses, pets, birds and people. Eventually the entire town of Times Beach was evacuated and declared a superfund site because the same contaminated oil found its way into the Spring River (SJRW 45).

The list of similar stories is lengthy (SJRW 48):

1962-1970: The American military in Vietnam extensively sprays Agent Orange, a potent defoliant and herbicide contaminated with dioxin. Decades later, exposed veterans have an increased risk of developing diabetes and multiple cancers.

1971: Scientists at the National Institute of Environmental Health Sciences determine that fetal exposure to dioxin causes developmental abnormalities in laboratory animals, including cleft palates and kidney malformations.

1976: Dioxin is released in an accident at a pesticide manufacturing plant in Seveso, Italy, contaminating people, air, soil and water. Decades later, scientists find adverse effects on reproductive function, including infertility and low sperm counts; lowered male/female sex ratio in newborns; changes in hormones; diabetes; cardiovascular effects; and elevated incidence of certain cancers nationwide.

1985: EPA publishes its "Health Assessment Document for Polychlorinated Dibenzo-p-dioxins," classifying dioxin as a known animal carcinogen and probable human carcinogen (EPA 1985). The EPA's Science Advisory Board (SAB) reviews EPA's assessment, the first of five reviews of dioxin's toxicity and carcinogenicity that SAB conducts between 1985 and 2010. SAB agrees with the EPA's overall approach but calls the evidence for carcinogenicity of dioxins in humans "uncertain".

1986: A joint publication of the EPA and the Midwest Research Institute based on EPA biomonitoring data concludes that dioxin-like pollutants "are prevalent in the general U.S. population".

1986: Research by Greenpeace and other activist groups uncovers collusion between EPA and the paper bleaching industry to keep secret the detection of dioxin in discharges from paper mills and in finished paper products.

1987: Leaked documents from the American Paper Institute reveal industry's strategy to "Get EPA to 'rethink' dioxin risk assessment" so as to avoid liability and "unnecessary changes" in production processes prompted by "unsound scientific data".

1988-1989: The Science Advisory Board reviews for the second time EPA's dioxin assessment, presented in two draft documents: "A Cancer Risk-specific Dose Estimate for 2,3,7,8-TCDD" and "Estimating Exposure to 2,3,7,8-TCDD".

1990: The Chlorine Institute, an industry trade group, starts a public campaign claiming that dioxin is "much less toxic to humans than originally believed," misrepresenting scientific opinion on its dangers.

1991: EPA administrator Bill Reilly tells The New York Times: "We are now seeing new information on dioxin that suggests a lower risk assessment for dioxin should be applied". EPA launches its second reassessment of dioxin.

1992: The International Joint Commission (IJC) for the U.S. and Canada issues its Sixth Biennial Report on Great Lakes Water Quality, highlighting evidence that the developing fetus is likely more sensitive to toxic contaminants than adults are.

1994: EPA releases a draft Health Assessment Document for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. The draft assessment concludes that these chemicals may be harmful at levels similar to those found in the general public, increasing the risk of cancer and causing potential damage to the immune, nervous and reproductive systems.

1995: EPA's Science Advisory Board completes its third review of EPA's dioxin assessment and agrees with the agency "the margin of safety (between background exposures and levels of exposure where effects have been observed in test animals) for dioxin-like compounds is smaller than the EPA usually sees for many other compounds.

1997: The International Agency for Research on Cancer declares dioxin a known human carcinogen.

1999: The United Nations Environment Program warns that dioxin is a concern for all countries and drafts an international treaty that would ban, phase out or limit production of 12 "persistent organic pollutants" (POPs). POPs are chemicals that

resist degradation, bioaccumulate through the food web and have a variety of adverse effects on human health and the environment. The United Nations POP list includes, among other substances, dioxin and other polychlorinated dioxins and furans.

2000: EPA publishes its Draft Final Report on "Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-P-Dioxin (TCDD) and Related Compounds."

2000: EPA updates its 1994 draft and submits its revised Dioxin Reassessment to the SAB. This is the SAB's fourth review of the dioxin assessment and culminates in publication of an SAB review document in 2001.

2000: The Food Industry Dioxin Working Group, representing beef producers, food processing, farming and retailing, urges the EPA to revise its dioxin assessment to lessen the chance that the assessment will "create a health scare."

2003: The EPA asks the National Academy of Sciences (NAS) to review the agency's draft dioxin reassessment, "Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds."

2003: The Food Industry Dioxin Working Group again pushes EPA to delay its dioxin assessment, calling for "additional research, data collection and more comprehensive government coordination... before any government action is contemplated."

2005: Japanese scientists publish a study finding that TCDD and related dioxins cross the human placenta and are detectable in cord blood). Scientists report finding dioxin-like compounds in cord blood samples from 10 of 10 newborns tested, further confirming the transfer of a mother's dioxin load to her child in utero.

2006: NAS publishes its report, "Health Risks from Dioxin and Related Compounds: Evaluation of the EPA Reassessment." NAS issues a press release titled "EPA assessment of dioxin understates uncertainty about health risks and may overstate

human cancer risk". In its 2010 draft, EPA has carefully considered the NAS recommendations by documenting alternative assessments, evaluating sources of uncertainty and providing the rationale for its proposed decisions.

2009: EPA releases its Science Plan for Activities Related to Dioxins in the Environment, promising to "accelerate the long-delayed scientific process to complete the assessment of the health risks dioxins pose to the public" and to publish a final report and assessment by the end of 2010.

2009: EPA Administrator Lisa Jackson pledges strong federal action to clean up a dioxin-contaminated Dow Chemical site in Michigan and to accelerate the assessment of dioxins' human health impacts.

May 2010: The agency publishes "EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments." The SAB initiates its fifth review of EPA's dioxin assessment.

June 2010: The SAB and EPA announce that the SAB review will be extended into Fall 2010. The chemical industry and the Department of Defense submit extensive comments seeking to delay or weaken the proposed EPA standards for dioxin.

Dioxin and related dioxin-like contaminants form as byproducts of processes that involve chlorine and chlorine containing substances, including pesticide and paper manufacturing and municipal waste incineration. Scientists first learned of dioxin's toxicity since the late 19th century, when German chemical industry workers exposed to it developed painful, oozing skin lesions known as chloracne. In the 1980s the U.S. Environmental Protection Agency (EPA) began a protracted process in order to issue a comprehensive human health risk assessment for dioxin. To date this process has included four Science Advisory Board (SAB) reviews (1984, 1988, 1995, and 2001) and a National Academy of Sciences review (2006). Plagued by delays forced by pressure from the chemical and defense industries, EPA has not yet completed that assessment. EPA first declared 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD, often referred to as dioxin) to be a probable human carcinogen in 1985. In

1997 the International Agency for Research on Cancer classified dioxin as "carcinogenic to humans," and in 2001 the National Toxicology Program, a government research agency that is part of the National Institutes of Health, also classified dioxin as a known human carcinogen. EPA has proposed updating its own classification to deem dioxin a definite "human carcinogen." Both the defense and chemical industries are objecting, continuing a decades-long pattern of trying to slow EPA's review and weaken its findings (SJRWP 48).

VII. DIOXINS AND THE PAPER INDUSTRY

One of the main sources of dioxin contamination is from chemical industrial sources, which includes the manufacture of chlorinated chemicals, pulp and paper industry, dry cleaning distillation residues, and others (SJRWP 38).

Although it had been known for some time that dioxin and related contaminants are present in almost all industry processes involving chlorine, the first reported occurrence in the peer reviewed scientific literature of a connection between pulp mill effluents and PCDD's and PCDF's was in 1986. Rappe et al., described samples of crab hepatopancreas and sediments collected outside a paper pulp mill on the Swedish west coast that showed levels of 2,3,7,8-tetraCDF and 2,3,7,8-tetraCDD 10 times higher than background samples. Numerous investigations on levels of PCDD's and PCDF's in various products and emissions from the pulp industry in Europe, USA and Canada have since been reported (SJRWP 37, 55).

Within the Swedish Dioxin Survey various samples from the pulp and paper industry and the chloralkali process have been analyzed by congener specific analytical methods. In addition to the generally discussed "bleaching pattern" of the tetrachlorinated congeners, these samples also contained higher chlorinated congeners like hexa-CDDs, hepta-CDFs, octa-CDD and octa-CDF. Counted as Nordic Toxic Equivalents (NTEQ), recycled pulp samples had the highest contamination level followed by thermomechanical pulp (TMP), unbleached sulfite and bleached softwood and hardwood. In addition to the bleaching process, various chemicals

used in the pulping, bleaching and wastewater treatment can contribute to the contamination (SJRWP 37).

Rappe and coworkers have stated, "After some initial controversy it is now generally accepted that bleaching of pulp using free chlorine can generate PCDDs and PCDFs". They analyzed more than 600 samples from pulp mills and pulp bleaching, and in all cases observed the presence of a typical "bleaching pattern" including 2,3,7,8- and 1,2,7,8-tetraCDF and 2,3,7,8-tetraCDD" (SJRWP 37).

Samples of effluents, sludge, pulp, final products (paper) and soil were collected from the identified pulp and paper mills in India. The samples were analyzed for 2,3,7,8-tetrachlorodibenzo- p-dioxin (2,3,7,8-TCDD) and other dioxin congeners and precursors. Pulp and paper mills using chlorine for the bleaching process showed the presence of 2,3,7,8-TCDD in effluent samples. In the effluent and pulp samples from mills where chlorine dioxide was used as a bleaching agent, the 2,3,7,8-TCDD congener ranged from below the detection limit 0.05 to 0.12 ng L⁻¹/ng g⁻¹. The relative standard deviation of reproducibility and the percent recovery of 2,3,7,8-TCDD were 2.07 and 82.4% in pulp and 2.8 and 92% in effluent, respectively. The 1,3,6,8-TCDD was the only other major dioxin congener found in the treated and untreated effluent and sludge samples. However, dichlorobenzene, trichlorophenyl, and hexachlorobiphenyl were detected in all samples (SJRWP 39).

Once aware of the presence or formation of PCDD/PCDF in an industrial process, measures may be taken to eliminate these sources or to minimize dioxin formation by changing the production process (SJRWP 38). Dioxin contamination can be reduced or minimized if pulp and paper mills use chlorine dioxide or chlorine-free bleaching agents rather than chlorine for bleaching pulp. When bleaching is with chlorine, the most effective method for minimizing the formation of 2,3,7,8-TCDD is by lowering the ratio of applied chlorine to residual lignin in unbleached pulp. Replacement of chlorine with chlorine dioxide in the first stage of pulp bleaching is an effective way to achieve this reduction (SJRWP 39). In other words, it is clear that using modern technology, including good washing, prebleaching using oxygen

and low chlorine multiple and the use of chlorine dioxide, high quality bleached pulp can be produced with very low contamination levels of dioxins (SJRWP 37).

VIII. DIOXINS IN THE SAN JACINTO WASTE PIT AND THE GALVESTON BAY SYSTEM

A. Studies of Dioxins and Furans in Sediment Samples taken from San Jacinto Waste Pit and the Galveston Bay System.

1. TCEQ Sediment Samples (2005)

The Houston Ship Channel Toxicity Study, in 1995, reported unexplained, high concentrations of dioxins in sediment samples in the vicinity of the San Jacinto River where it flows under the I-10 Bridge. The nearby San Jacinto River Waste Pit was suspected to be a major source of these contaminants. In 2005, seven sediment samples were collected just below the surface layer (1 to 8 feet below the surface of the water for submerged locations) from the SJRWP site by the TCEQ (SJRWP 53). An additional four sediment samples were collected off-site (two from approximately 3 miles up-stream and two from approximately 4 miles down-stream). Each sediment sample was measured for 15 of the 17 PCDD/PCDF congeners with 2,3,7,8-TCDD-like toxicity or carcinogenicity [the octachlorodibenzo-p-dioxin (OCDD) and octachlorodibenzofuran (OCDF) concentrations were not reported] (SJRWP 31, 53).

2. University of Houston TMDL Sediment Samples (2002 to 2005)

As part of the total maximum daily load (TMDL) study of dioxins in the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay, the University of Houston collected 210 sediment samples from 84 different locations throughout the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay from 2002 through 2005. Two of these samples (SE-15 and SE-15dup) were collected on the SJRWP site between pits B and C and close to the northwest extreme of pit B. The remaining 208 sediment samples were collected throughout the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay waterway system. The 210 TMDL samples

were measured for all 17 of the PCDD/PCDF congeners having TCDD-like toxicity (*SJRWP 61, 61a, 62*).

3. Dredging Activities Impact on Dioxins in Surface Sediments (2009)

Since 1914, dredging operations to establish, sporadically expand, and consistently maintain a navigable channel for large ships has been and remains continuous in the Houston Ship Channel (HSC). This research focuses on determining if dredging activities have any significant impact on the quantities of dioxins associated with surface sediments in the HSC and Galveston Bay in general. Four transects were sampled, located on the dredged and undredged sides of two dredge-spoil islands (Alexander and Hog Islands). Sediment samples were characterized in terms of their organic carbon contents, grain size fractions, indicator dioxin concentrations (2,3,7,8-tetrachlorinated dibenzo-p-dioxin [TCDD], 2,3,7,8 tetrachlorodibenzofuran [TCDF], and toxic equivalents) (*SJRWP 12*).

4. Baylor University Studies in Biota-Sediment Accumulation Factors (2010)

The Texas Environmental Health Institute (TEHI), a collaborative effort between Texas Department of State Health Services (TDSHS) and Texas Commission on Environmental Quality (TCEQ), funded this research project in Baylor University's Center for Reservoir and Aquatic Systems Research (CRASR) for research efforts to understand bioaccumulation of dioxins, furans, and PCBs at the SJRWP. The specific research objectives of the study included: 1) measurement of concentrations of dioxins, furans, and PCBs in fish, invertebrates, and sediment samples at the SJRWP, 2) estimation of site-specific biota sediment accumulation factors (BSAF) values for targeted invertebrates and fish, 3), delineation of trophic position of sampled food web members at the SJRWP site using stable isotope approaches, 4) modeling of bioaccumulation of dioxins, furans, 5) explore use of quantitative structure activity relationship (QSAR) models for BSAF values, and 6) establishment of a combined approach to determine site-specific BSAFs for other contaminated sites (*SJRWP 13*)

5. U. S. EPA Study for Superfund Site Characterization (2010)

This Preliminary Site Characterization Report (PSCR) has been prepared on behalf of International Paper Company (IPC) and McGinnes Industrial Maintenance Corporation (MIMC), pursuant to the requirements of Unilateral Administrative Order (UAO), Docket No. 06-03-10, which was issued by the U.S. Environmental Protection Agency (USEPA) to IPC and MIMC on November 20, 2009. The 2009 UAO directs IPC and MIMC to conduct a Remedial Investigation and Feasibility Study (RI/FS) for the San Jacinto River Waste Pits (SJRWP) Superfund Site in Harris County, Texas (the Site). The UAO provides for two Site characterization deliverables, the PSCR and the RI Report. This document meets the requirements of the UAO by presenting the initial Site characterization, which includes summaries of all of the information collected to date under the RI and some initial data analyses. The UAO describes in its findings of fact a basic history of the Site, but it addresses only the impoundments that are located on the north side of Interstate Highway 10 (I-10). USEPA has subsequently required investigation of soil in an area to the south of I-10, citing historical documents indicating possible waste disposal activities in that area.² This document addresses these two impoundment areas separately, as the “northern impoundments,” or “impoundments north of I-10” and the “southern impoundment,” or “impoundment south of I-10.” The distinction primarily applies to information on soil. Where this distinction is not made (e.g., for sediment studies or tissue), the text and data analyses address the Site overall. This PSCR presents information on the investigations that have been performed since the UAO was issued, and describes the location and characteristics of surface and subsurface features and contamination at the Site. The location, dimensions, physical conditions, and concentrations of chemicals in the source materials, which are primarily paper mill wastes deposited on the Site in the 1960s, are described. Initial findings with respect to the extent of chemical migration through affected media are also described in this document. Chemical migration is still under investigation; additional chemical

fate and transport analysis will be addressed in detail in the Chemical Fate and Transport Modeling Report. In addition to presenting the information required by the UAO, this PSCR presents (SPRWP 58).

B. Concentrations of Dioxins and Furans in Sediment Samples taken from San Jacinto Waste Pit and the Galveston Bay System.

1. TCEQ and UH Studies (SJRWP 31)

Grouping of TCEQ and UH Samples for Analysis

Sediment samples were grouped by the Texas Department of State Health Services (DSHS) into five geographical categories: 1) those collected on the SJRWP site (the two TMDL samples and seven TCEQ samples); 2) those collected down-stream from the SJRWP site in the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay (59 samples); 3) those collected from the San Jacinto River in the immediate vicinity of the SJRWP site (31 samples); 4) those collected from the Houston Ship Channel above (west) of its confluence with the San Jacinto River (62 samples); and 5) those collected up-stream from the SJRWP site or up various tributaries to the San Jacinto River, Houston Ship Channel, or Upper Galveston Bay (56 samples).

TCDD TEQ Concentrations at the SJRWP site

Of the nine sediment samples collected on the SJRWP site, all but one had a 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalency (TCDD TEQ) concentration greater than 1,000 picograms per gram (pg/g). The average TCDD TEQ concentration for the nine site samples was 15,594 pg/g (range: 80.9 – 34,028 pg/g). In comparison, TCEQ's upstream and downstream "background" sediment TCDD TEQ concentrations for four samples averaged 1.85 pg/g (range 1.27 – 2.77 pg/g) (SJRWP 31). Sample core sites are shown in EXHIBIT I.

TCDD TEQ Concentrations at Other Locations in Area Waterways

For comparison purposes, DSHS reviewed TCDD TEQ concentrations measured at other locations in the San Jacinto River/Houston Ship Channel/Upper Galveston Bay waterway system by the University of Houston under the TMDL Project (EXHIBIT II). Downstream TMDL samples were found to have an average TCDD TEQ concentration of 13.8 pg/g (range: 0.739 – 86.2 pg/g), site vicinity TMDL samples averaged 82.2 pg/g (range: 2.00 – 573 pg/g), Houston Ship Channel TMDL samples averaged 65.7 pg/g (range: 4.90 – 857 pg/g), and upstream or tributary TMDL samples averaged 16.0 pg/g (range: 0.759 – 103 pg/g) (SJRW 31).

2. Dredging Study (SJRW 12)

Only the most toxic of the dioxin congeners (2,3,7,8-TCDD and 2,3,7,8-TCDF) and TEQ values are studied. Each of the four transects studied was composed of 9 sites. In general, sedimentary concentrations of these dioxin congeners and TEQs were generally higher at transects near Alexander Island (N) than at those near Hog Island (S); they were somewhat higher at undredged than at dredged transects. The data are shown in graphically in EXHIBIT III.

While this research focused on the sampling of surface (< 4 cm) sediments at only four transects in the HSC, the data provide strong support for a couple of conclusions: (1) sedimentary dioxin concentrations are significantly higher at transects sampled adjacent to Alexander Island as compared with Hog Island, which is most likely due to the closer proximity of Alexander Island to the San Jacinto waste pits; (2) while mean dioxin concentrations were slightly higher for undredged as compared with dredged transect samples as a whole, these differences were not significant. The location of the southern [Hog Island] and the northern [Alexander Island] with respect to the SJRW is shown in the aerial view in EXHIBIT IV.

3. Baylor University Studies (SJRW 13)

Fifteen sediment samples were taken from the submerged eastern part of the San Jacinto River Waste Pit site. Sediment samples were taken at a depth of from 4 to 10 cm. Analyses are shown for PCBs as well as 2,3,7,8-TCDD and 2,3,7,8-TCDF in the figure taken from the manuscript and shown below. Values for 2,3,7,8-TCDD range

from 3.7 to 17,000 pg/g dry wt. with a mean value of 2,700. Values for 2,3,7,8-TCDF range from 36 to 50,000 pg/g dry wt. with a mean value of 8,700. Data are shown graphically in EXHIBIT V along with companion measurements of PCBs.

***4. Dioxin concentrations from U. S. EPA Study for Superfund Site
Characterization (Extracted and condensed from SJRWP 58)***

In response to the requirements of a Unilateral Administrative Order from the U. S. EPA, International Paper Company and McGinnes Industrial Maintenance Corporation have prepared a Preliminary Site Characterization Report on the San Jacinto River Waste Pits Superfund Site. Among other data, this report contains a fine summary of new and existing PCDD and PCDF concentrations in the sediments in and near the site impoundments located on the north side of Interstate Highway 10 (I-10).

Dioxin contamination data are given for both surface and subsurface sediments and soils and both in and around the waste pit site.

Surface sediment contamination

Surface sediment samples taken from 0 to 6 inches below ground surface (bgs) were collected at 120 locations within the preliminary Site perimeter (including data from URS 2010). The distribution of dioxins and furans in surface sediments, expressed as TEQ_{DF} (ng/kg), is shown for the central portion of the Site in EXHIBIT VI (Figure 6-11 of SJRWP 58). EXHIBIT VII (Figure 6-12 of SJRWP 58) shows TEQ_{DF} concentrations in surface sediment throughout the Site, and EXHIBIT VIII (Figure 6-13 of SJRWP 58) provides a detailed illustration of TEQ_{DF} concentrations at the surface of the impoundments north of I-10, and in surface sediments surrounding the northern impoundments. TEQ_{DF} values in upstream background areas are shown as dry weight concentrations in EXHIBIT IX (Figure 6-14 of SJRWP 58).

Summary statistics for dioxins and furan concentrations in surface sediment describing the number of samples, detected measurements, detection frequency, and the minimum, maximum, and mean of detected values are presented in dry weight in EXHIBIT X (Table 6-3 of SJRWP 58).

With this dataset, the extent of dioxin and furan contamination is well defined.

Dioxin and furan concentrations in surface sediments, expressed as TEQ_{DF} concentrations, are substantially higher within the 1966 perimeter of the northern impoundments than elsewhere on the Site. Within the 1966 perimeter, TEQ_{DF} concentrations in surface sediments are highest in the western cell (Figures 6-11 and 6-13). TEQ_{DF} concentrations in surface sediment outside of the northern impoundment are typically 3 to 4 orders of magnitude lower than within the impoundment, even in areas directly adjacent to the 1966 impoundment perimeter (SJRWP 58).

Surface sediment TEQ_{DF} concentrations upstream and downstream of the northern impoundment are lower than within the northern impoundment footprint (Figures 6-11 and 6-12). The highest TEQ_{DF} concentrations in surface sediments north of I-10 (Figure 6-12) are located in the eastern side of the upland sand separation area, approximately 500 to 700 feet northeast of the northern impoundment. TEQ_{DF} concentrations downstream of the northern impoundment (Figure 6-12) are lowest along the eastern cutbank side of the river south of I-10, in the Old River to the west and southwest of the peninsula south of I-10, and in the river thalweg, particularly north of I-10. Along the southern boundary delineated by USEPA's preliminary Site perimeter, TEQ_{DF} concentrations in surface sediment are 6.12 ng/kg and below. In surface sediments south of I-10, TEQ_{DF} concentrations along a line from west to east at the southern tip of the peninsula are relatively elevated (Figure 6-12), ranging from 49.3 to 52.6 ng/kg at three locations. Surface sediment TEQ_{DF} concentrations in the

upstream background area (Figure 6-14) are comparable to the lowest concentrations in surface sediments on the Site. All TEQ_{DF} concentrations in the upstream background area are less than 6 ng/kg, with the highest measured TEQ_{DF} concentration (5.72 ng/kg dry weight) to the west of the preliminary Site perimeter (SJRWP 58).

Subsurface sediment contamination

Subsurface sediment samples are those samples taken from intervals greater than 6 inches bgs. Subsurface sediment samples were collected for chemical analysis at 22 locations as shown in EXHIBIT XI (Figure 6-15 of SJRWP 58), resulting in 124 subsurface sediment samples. The distribution of dioxins and furans in deep subsurface sediments, expressed as TEQ_{DF}, are shown in Figure 6-15. TEQ_{DF} concentrations in cross sections through the northern impoundment are shown in EXHIBIT XII (Figure 6-16 of SJRWP 58) and EXHIBIT XIII (Figure 6-17 of SJRWP 58). Summary statistics for dioxins and furan concentrations in subsurface sediment describing the number of samples, detected measurements, detection frequency, and the minimum, maximum, and mean of detected values are presented in dry weight measurement in EXHIBIT XIV (Table 6-10 of SJRWP 58).

The highest TEQ_{DF} concentration (31,600 ng/kg) occurs in the upper 2-foot interval of the core from Station SJGB014, the boring located in the north-central portion of the impoundment (EXHIBIT XI, Figure 6-15), but cores surrounding it to the north, east, and southeast show much lower concentrations at all intervals, even if they occur within the 1966 impoundment perimeter. Cores within the western cell tend to show higher TEQ_{DF} concentrations throughout the upper core increments. All TEQ_{DF} concentrations decrease from their maximum with depth within a given core indicating that the peak concentrations have been located in the vertical dimension. TEQ_{DF} is below 7 ng/kg in the lower-most interval measured in all but three borings.

The three exceptions occur in the western portion of the northern impoundment where TEQ_{DF} concentrations within the bottom interval range from 25.2 to 17,700 ng/kg.

Subsurface sediment TEQ_{DF} concentrations in two locations, one west of the impoundments (SJNE026) and the other to the north (SJNE033), are slightly elevated relative to their surface sediment counterparts (Figures 6-12 [EXHIBIT VII] and 6-15 [EXHIBIT XI]). The highest subsurface sediment TEQ_{DF} concentrations north of I-10 and outside the 1966 impoundment perimeter are in a core located in the eastern side of the upland sand separation area, in the 3- to 4-foot bgs (349 ng/kg) and 5- to 6-foot bgs (339 ng/kg) intervals (Figure 6-15). TEQ_{DF} concentrations downstream of the northern impoundment, south of I-10, are generally much lower than elsewhere on Site, except at Station SJNE007, where the maximum subsurface TEQ_{DF} concentration (51.1 ng/kg) occurs at the 3- to 4-foot depth interval. In other sediment cores south of I-10, the maximum subsurface sediment TEQ_{DF} concentration was 7.41 ng/kg.

Soil Contamination

For soils, summary statistics were developed within four areas. The subareas used in the summary statistics tables are shown on Figure 5-5 and are described below:

1. Area 1 is the denuded portion of the upland sand separation area, where historical aerial photographs suggest that sediment handling took place, and the area surrounding the road that provides access in and out of this upland area
2. Area 2 is the portion of the Site beneath I-10, in the TxDOT right-of-way (ROW), that was sampled for the TCRA (Anchor QEA 2010)
3. Area 3 is the area of the impoundments north of I-10

4. Area 4 is the area of soil investigation south of I-10 (results are presented in Section 7.1).

Text and figures in this section focus on dioxins and furans; summary statistics for dioxins and furan concentrations in surface soils describing the number of samples, detected measurements, detection frequency, and the minimum and maximum of detected values and the overall mean are presented in dry weight in Table 6-17 (EXHIBIT XV). Table 6-19 (EXHIBIT XVI) presents the same summary statistics for subsurface soils in dry weight.

Subsurface soils (below 6 inches deep) were collected at most soil sampling locations. Core samples for chemical analysis in soils were only collected from Area 4. Summary statistics presented include the mean, calculated with all data including nondetects substituted at one-half the detection limit, the range of detected values, and detection frequencies. The distribution of dioxin and furans in surface and shallow subsurface soils in Areas 1 to 3, expressed as TEQ_{DF}, is shown in EXHIBIT VI (Figure 6-11 of SJRWP 58).

Surface Soil

North of I-10 in Areas 1 to 3, the highest averages of dioxin and furan concentrations in surface soils occurs in Area 3 (Table 6-17 [EXHIBIT XV]), which encompasses the northern impoundments. In Area 3, which has the highest average TEQ_{DF} concentration at the surface of all four investigation areas, the maximum TEQ_{DF} concentration in surface soils (11,200 ng/kg) occurs in the southern portion of the western cell of the impoundments at Station SJGB009. Within Area 3, the highest average congener concentration was for 2,3,7,8-TCDF at 5,480 ng/kg (Table 6-17). In other soil study areas, the congener with the overall maximum and the highest average concentration in surface soils is OCDD.

Average and maximum TEQ_{DF} concentrations in surface soils in Area 1 and in Area 2 are much lower than within the northern impoundments (Table 6-17 [EXHIBIT XV]). The maximum TEQ_{DF} values in Areas 1 and 2 were 27.2 ng/kg and 66.1 ng/kg at Stations SJTS010 and TXDOT005, respectively.

Subsurface Soil

In subsurface soils north of I-10, the highest average concentration of dioxins and furans in Areas 1–3, occurs in Area 3 (Table 6-19 [EXHIBIT XVI]). In Area 3, the highest TEQ_{DF} also at Station SJGB009. Consistent with surface soils within Area 3, the highest average congener concentration was for 2,3,7,8-TCDF at 15,300 ng/kg (Tables 6-19 [EXHIBIT XVI]).

Subsurface soil TEQ_{DF} concentrations in Area 1 and in Area 2 are generally lower than those within Area 3, the northern impoundments (Table 6-19). The maximum TEQ_{DF} concentration in subsurface soils of Area 1 was 195 ng/kg and occurs at station SJTS018, in the northeastern corner of the upland sand separation area, in the vicinity of surface and subsurface sediment samples with relatively elevated TEQ_{DF} concentrations. In Area 2, the TxDOT ROW, the maximum TEQ_{DF} of the two subsurface soil samples was 1.22 ng/kg. The congener with the highest concentrations in subsurface soils in Areas 1 and 2 is OCDD, which is consistent with patterns in the surface soils from these areas.

Summary of the Preliminary Assessment of the Nature and Extent of Contamination

General observations about dioxins and furans in abiotic media include the following:

- The highest concentrations of dioxins and furans across the entire Site are in soils and sediments within the original 1966 perimeter of the impoundments north of I-10, both at the surface and in subsurface materials. However, even

within the eastern cell of the northern impoundments, several cores show very low TEQDF concentrations in all depths. TEQDF concentrations in some surface samples within the 1966 perimeter, in the upper northeastern extent, are also not highly elevated.

- Cores collected from the western cell of the northern impoundments show substantially elevated concentrations of TEQDF throughout most depth intervals, and in all cases, the peak concentration within the core occurs above intervals with lower concentrations. In all but two sediment cores north of I-10, the deepest interval has a TEQDF less than 26 ng/kg, and in one of the remaining two; the deepest interval has a TEQDF of 194 ng/kg. One core from the western cell, SJGB012, showed a TEQDF concentration of 17,700 ng/kg at its deepest depth. These results suggest that the sediment cores within the northern impoundments penetrated the bottom of the waste deposit, except at SJGB012.
- In both surface and subsurface sediments, the dioxin and furan concentrations outside of the 1966 northern impoundment perimeter are substantially below concentrations within the perimeter in the western cell. The maximum concentrations in sediments outside of the 1966 perimeter are in the vicinity of the northeastern corner of the upland sand separation area. Whereas one of these sediment locations (SJNE041) has an adjacent core that shows no notable subsurface dioxin and furan contamination, the other (SJNE032), does show elevated TEQDF concentrations in several subsurface intervals.
- TEQDF concentrations in soils of the upland sand separation area and the TxDOT ROW are generally low. The maximum TEQDF concentration at the soil surface in the upland sand separation area (Area 1) is 27.2 ng/kg (the maximum TEQDF concentration in background area soils was 23.1 ng/kg, Table 6-47), and in the TxDOT ROW is 66.1 ng/kg, at station TxDOT004, directly adjacent to the northern impoundment perimeter. Subsurface soil in

one location, in the northeastern corner of the upland sand separation area, and from 12 to 24 inches deep, was relatively elevated at 195 ng/kg.

- Based upon existing testing and data, groundwaters in both the alluvial unit and in the Chicot Aquifer have not been demonstrated to be contaminated by paper mill waste-related dioxins and furans.

IX. COMPARISON OF SEDIMENT CONTAMINENTS IN THE SJRWP WITH SLUDGE DATA FROM PAPER MILLS IN OTHER STUDIES

During the conference DIOXIN '86 in Fukuoka, Japan Rappe et al. reported that samples of crab hepatopancreas and sediments collected outside a pulp mill on the Swedish west coast had elevated levels of PCDDs and PCDFs when compared to background samples. This was the first report in the refereed scientific literature of a connection between pulp mill effluents and PCDDs and PCDFs (SJRWP 37). Rappe collected samples of hepatopancreas from crustaceans from different locations along the Swedish West Coast and analyzed them. The crab samples from the locations Grebbestad and Idefjord were not near the pulp mill and should represent background levels, while Varofjord represents a potential point source from the pulp mill using chlorine in their bleaching processes. The results are shown in EXHIBIT XVII (Table 2 of SJRWP 55).

Low levels of a series PCDDs and PCDFs were found in both crab hepatopancreas background samples. The sample from the Varofjord paper mill area contained much higher levels of some congeners, especially 2,3,7,8-tetra-CDF and 2,3,7,8-tetra-CDD. This is a strong indication that paper mills could be a source of highly toxic PCDDs and PCDFs. Rappe et al. also analyzed two sediment samples, one collected in the sedimentation lagoon in the pulp mill (Varo Mill) and the other in the mouth of the nearby Viskan River. The PCDDs and PCDFs in these two samples are also quite different, the sample from the pulp mill lagoon containing high levels of 2,3,7,8-tetra-CDF and 2,3,7,8-tetra-CDD compared with that from the river mouth (SJRWP 55).

In 1990, Rappe reported on levels of PCDDs and PCDFs in samples obtained from paper pulp mills using various processes. The major conclusion reached in this paper is that bleaching of pulp using free chlorine can generate PCDDs and PCDFs. Rappe states that in his laboratory they have now analyzed more than 600 samples from pulp mills and pulp bleaching, and in all cases we have observed a typical "bleaching pattern" including 2,3,7,8- and 1,2,7,8-tetraCDF and 2,3,7,8-tetraCDD (1,2). It has also been shown that the contamination levels can be highly reduced by using less chlorine, partially substituting by chlorine dioxide as well as prebleaching with oxygen (SJRWP 37).

The National Dioxin Study (SJRWP 41), published in 1987, found 2,3,7,8-tetrachlorodibenzo-p-dioxin (2378-TCDD) in native fish collected downstream from a number of pulp and paper mills (levels from <5 to 85 parts per trillion (ppt)), and subsequent findings of 2378-TCDD in bleached kraft pulp and paper mill wastewater sludges (levels from <10 to 414 ppt). As a result of this study the United States Environmental Protection Agency (USEPA) planned a detailed process evaluation study at one mill. Through subsequent discussions with the paper industry, USEPA and the industry agreed in June 1986 to conduct a cooperative screening study of five bleached kraft pulp and paper mills on a shared resource basis. Three mills were selected on the basis of known 2378-TCDD levels in sludges and two mills were volunteered by their parent companies to attain the geographical diversity desired for the study. Although the study attempted a mass balance approach by looking at all inputs and outputs from the mills, the most important findings related to the San Jacinto River Waste Pit are those focused on wastewater sludges. The study reported concentrations of 2378-TCDD and 2378-TCDF reported as ppt by dry weight. For wastewater sludges, the concentration of 2378-TCDD ranged from 3.3 to 189 ppt with a median value of 37 ppt and a mean value of 56 ppt (SJRWP 40). This material would in my estimation be the substance most equivalent to the input to the San Jacinto River Waste Pit.

Finally, in March of 1988 the U.S. Environmental Protection Agency (EPA) and the U.S. pulp and paper industry jointly released the results of a screening study that

provided some of the first comprehensive results on formation and discharge of chlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) in pulp and paper mills. This early screening study of five bleached kraft mills ("Five Mill Study") confirmed that the pulp bleaching process was primarily responsible for formation of the PCDDs and PCDFs. The partitioning of these compounds between the bleached pulp, wastewater treatment sludge, and final effluent was found to be highly variable among the five mills. The study also indicated that 2,3,7,8-tetrachlorodibenzo-p-dioxin (2378-TCDD) and 2,3,7,8-tetrachlorodibenzofuran (2378-TCDF) were the principal PCDDs and PCDFs formed (SJRWP 42).

To provide the EPA with more complete data on the release of these compounds by the U.S. industry, a new screening study was initiated in April 1988 to further characterize all 104 U.S. mills that practice chlorine bleaching of chemically produced pulps (2). The scope of the study was developed by EPA and industry, and the study was managed by NCASI with EPA overview. The data from this study provide an estimate of the release of 2378-TCDD and 2378-TCDF in three environmental export vectors (bleached pulp, sludge, and effluent) of the U.S. industry as of mid to late 1988. A review of this study includes the results of analyses of wastewater effluent and sludge (SJRWP 42). Data for Kraft mills and sulfite mills are summarized separately. EXHIBIT XVIII (Tables 3 of SJRWP 42) summarizes the data for the distribution of TCDD/F concentrations in the sludge. Concentrations are in nanograms per kilogram (ng/kg) of dry material. This unit is equivalent to picograms per gram (pg/g).

Note that the values for both 2378-TCDD and 2378-TCDF are high (particularly for the Kraft Mills) and consistent with the results of other pulp mills that use chlorine in the bleaching process

For comparison, the results of chemical analyses for TCDD/F from sediment samples taken from the San Jacinto River Waste Pit are shown in EXHIBIT XIX (Table 5 of SJRWP 31).

In summary, the level of dioxins found in the sludge measurements from most paper mills as summarized above are high and consistent that the proposition that this sludge is equivalent to the sediment of the SJRWP.

X. IS THE SJRWP THE ONLY DIOXIN SOURCE IN THE GALVESTON BAY SYSTEM?

Dioxin contamination of surface waters and sediments may come from point sources (identifiable sources at specific locations such as wastewater outfalls) or nonpoint sources (multiple sources located across a relatively large area such as urban runoff). Whereas nonpoint sources are often associated with bacterial contamination and excess nutrient runoff, point sources are typically associated with chlorinated organic compounds such as polychlorinated biphenyls (PCBs) and dioxins. Given that Galveston Bay has had large industrial complexes such as those along the Houston Ship Channel and in Texas City operating along its shore for more than 50 years; it comes as no surprise that some areas of the Lower Galveston Bay watershed have problems with contamination of chlorinated organic compounds. Samples of chlorinated organic compounds are typically collected in the sediments rather than directly from the water column because of low water solubility and a high affinity for soil particles.

A question of major interest is: Is the SJRWP the only point source of dioxins in the Galveston Bay System? The answer to that question is complex, but may be rephrased as: Has any other site of high sediment dioxin concentrations been found? The answer to that question is in the existing data set.

The table shown in EXHIBIT XX (Table 9 of SJRWP 31) was published by the Texas Department of State Health Services in 2012 (SJRWP 31). It shows average values of tetrachlorodibenzo-p-dioxin toxic equivalents (TCDD TEQ) for sediment samples collected in various regions of the Galveston Bay System.

Using average values of these concentrations we see that the 9 samples collected from the SJRWP site averaged 15,594 pg/g, a value very much higher than seen in any other location. The next highest average concentration of 82.24 was from the

San Jacinto River near the Waste Pit. This value is almost 200 times smaller than found in the Pit itself. Third highest was 65.69 pg/g, derived from samples taken in the Houston Ship Channel. Lowest values for sediment contamination were 15.97 pg/g and 13.756 pg/g taken from sites up-stream and down-stream from the waste pit site, respectively. All off-site samples ranged from a minimum value of 0.739 pg/g to a maximum of 865.8 pg/g (taken from the Houston Ship Channel) with an average value of 40.04 pg/g. No other site showed a dioxin concentration that came within 5% of that from the SJRWP site.

Another way of interpreting the data is to place the various existing sediment dioxin data on a map of the Galveston Bay System as shown in EXHIBIT XXI. This map was shown in a presentation given in 2011 by a member of the University of Houston Civil and Environmental Engineering Group (SJRWP 85). In general, the dioxin concentration averages fall off from north to south. The highest contamination is at the SJRWP with other "lesser hot spots" showing up along the Houston Ship Channel and near the mouth of West Bay.

PCDD/PCDF concentrations in sediment samples were collected in the Houston Ship Channel and Lower San Jacinto River down to about Clear Lake during five major studies from 2002 to 2004 (SJRWP 61). Maps showing organic-carbon normalized total TEQ concentrations in sediment are shown in EXHIBIT XXII (SJRWP 61, Figures 3.5 and 3.6). For the Summer 2002 in-channel sediment samples, dioxin levels varied from 0.56 to 345.4 ng TEQ/kg-dry wt (dry weight), with an average value of 22.98 ng TEQ/kg-dry wt. Total TEQ levels for in-channel sediment samples collected in Fall 2002 ranged between 0.56 to 64.5 ng TEQ/kg-dry wt, with an average value of 18.7 ng TEQ/kg-dry wt. Dioxin concentrations in sediment samples collected in Spring 2003 ranged from 0.6 to 138.9 ng/kg-dry wt, with an average value of 15.98 ng/kg dry wt. For sediment samples collected in Spring 2004, dioxin levels varied from 0.92 to 451.4 ng TEQ/kg-dry wt, with an average value of 42.7 ng TEQ/kg-dry wt.

The highest TEQ levels were measured in samples from locations 15979 (345.43 ng TEQ/kg-dry wt) and 11193 (103.23 ng TEQ/kg-dry wt) during the Summer 2002 event and from location 11193 (63.89 ng TEQ/kg-dry wt) during Fall 2002. In-channel locations 11193 (138.96 ng TEQ/kg-dry wt) exhibited the highest dioxin levels during the Spring 2003 sampling event. The highest TEQ levels in the Spring 2004 samples were measured at locations 11280 (451.36 ng TEQ/kg-dry wt) and 11193 (91.27 ng TEQ/kg-dry wt), whereas the highest TEQ concentrations in Fall 2004 samples were measured at locations 11280 (846.28 ng TEQ/kg-dry wt) and 16499 (78.34 ng TEQ/kg-dry wt). Concentrations of total TEQ were not correlated with organic carbon content in sediment ($r_2 = 0.057$), even though the correlation was statistically significant ($p < 0.05$) (Figure 3.7). This suggests that the higher concentrations of dioxins in certain locations may be attributable to hydrological characteristics of the channel (sedimentation) or to the presence of active sources in certain areas of the HSC, rather than to a higher presence of organic material. Thus, during the 5 sampling events, sites 15979, 11193, 11280 and 16499 exhibited the highest levels of dioxin, suggesting that they either were sources or were near sources of dioxin.

Site 15979 was reinvestigated in detail during the summer of 2004. Five samples were collected along a transect to evaluate the difference in dioxin concentrations between the dredged channel and the channel banks. Concentrations of dioxins along the transect are presented in EXHIBIT XXIII (SJRWP 61, Figure 3.10). These data show that the concentrations in the main channel are higher than those measured at the banks.

Site 11193 is located on the San Jacinto River in a location very near to the SJRWP. When this fact became known a grid of sites was sampled around the waste pit in 2005. The dioxin total TEQ values (ng/kg) are shown in EXHIBIT XXIV (SJRWP 61, Figure 3.11) at the lower right corner of the site position characters. The TEQ values in ng/kg oc are given in the legend of the figure. One of the data points falls within the waste pit location and shows a TEQ of 32,752 ng/kg dry wt. This value is

far and above the largest dioxin concentration found in this study. Site 11 sits in an old abandoned sand mining operation to the west of the waste pit.

EXHIBIT XXV (SJRW 61, Fig. 3.4a and Fig 3.2) shows the location of Site 11280 and additional sites surrounding it sampled in 2005. EXHIBIT XXVI (SJRW 61, Figure 3.12) shows profiles of OC-normalized 2378-TCDD and TEQ concentrations at the 11 sampling locations in the main channel. The highest organic-carbon normalized TEQ concentrations were observed at locations 24 and 11268 for segments 1007 and 1006, respectively. Consistent with measurements from the Summer 2004 high-resolution sediment samples, both 2378-TCDD and TEQ levels at Station 11268 were significantly higher than those observed at the remaining locations in Segment 1006, which might suggest the presence of an identified source of 2378-TCDD. Finally, sampling conducted in 2004 showed very high concentrations in the vicinity of Site 11280. That and the fact that Summer 2005 results showed a peak at Location 24 may suggest the presence of an additional source somewhere between sites 11280 and 24.

Is it possible that the SJRW is responsible for all of the dioxins in the sediments of the Galveston Bay System? How much dioxin would this be? Excepting the high concentrations in the ship channel, most of the bay system has an average dioxin level of approximately 15 pg/g TEQ dry wt. Suppose this is all in the top 10 centimeters of the sediment. If the average dry weight of the sediment were 1600 kg/m³, a cubic meter of sediment would contain $1.6 \times 10^6 \times 15 \times 10^{-12} = 2.4 \times 10^{-5}$ grams dioxin TEQ. Thus, at 10 cm depth, this cubic meter would cover an area of 100 sq. m. The amount of dioxin that is spread about the Galveston Bay averages then, about 3.4×10^{-7} gm/sq m. The Galveston Bay System is approximately 600 sq miles or 1.6×10^9 sq m. The total dioxin in the sediments of Galveston Bay can thus be estimated as $1.6 \times 10^9 \times 2.4 \times 10^{-5} = 3.8 \times 10^4$ grams or about 38 kg of dioxin TEQ. Now, the waste pit has 32,759 ng TEQ dioxin/kg or 32,759 pg/g sediment. But the depth of the waste pit is probably greater than 3 meters. It is also about 10 hectares or 10^5 sq m. Roughly, then, its volume is 3×10^5 m³. Thus its total dry wt. is $1.6 \times 10^6 \times 3 \times 10^5 = 4.8 \times 10^{11}$ grams of sediment. The total amount of dioxin in the waste

pit is thus $3.27 \times 10^4 \times 10^{-12} \times 4.8 \times 10^{11} = 15.7 \times 10^3$ grams of dioxin TEQ or approximately 16 kg dioxin TEQ. The estimated amount of dioxin in the sediments of Galveston Bay is approximately 38 kg TEQ and the estimated amount of dioxin remaining in the waste pit is approximately 16 kg TEQ. Thus if the waste pit has lost approximately twice the amount of dioxin that it currently has, it could theoretically have accounted for all of the dioxin in the sediments of Galveston Bay. The fact that these numbers are even reasonably consistent is extraordinary in my mind. But it does suggest that the SJRWP is a major contributor to the total dioxin pollution of the Galveston Bay System and will remain so!!

Summarizing the above arguments, the San Jacinto River Waste Pit is the only significant point source of dioxins that has been found in a series of fairly extensive searches for dioxins in the sediments of the Galveston Bay System, including the Houston Ship Channel. Finally, the SJRWP current level of dioxin contamination is consistent with the statement that it is possibly the only major source of dioxin contamination in the Galveston Bay-Houston Ship Channel System.

XI. DIOXIN LIFE TIME IN THE SEDIMENT ENVIRONMENT

PCDDs and PCDFs are highly persistent compounds that have been detected in air, water, soil, sediments, animals and food. PCDDs and PCDFs partition strongly to soils and sediments where, due to their low vapor pressure, low aqueous solubility and strong sorption to organic matter, they become generally immobile (SJRWP 9). In general, higher chlorinated PCDDs are likely to volatilize more slowly from soil than lower chlorinated congeners (SJRWP 24).

Most biological and abiotic transformation and degradation processes for PCDDs are slow, with photolysis in sunlight being the most rapid (SJRWP 24). This is illustrated by the relatively shorter half-life of 2,3,7,8-TCDD in surface soils (9–15 years) compared with 25–100 years in the sub-surface (SJRWP 24). It has been observed that over 50 per cent of the PCDDs and PCDFs present in a sludge-amended soil in

1972 were still present in 1990, and that the uniform reduction in all homologues was indicative of physical loss of material (SJRWP 24).

One of the measurements that have been reported herein is the fact that the concentration of dioxins in the SJRWP measures 32,752 ng/kg dry wt. Suppose we assume that the half-life of the dioxins in the waste pit averages 50 years. Some will be exposed to air and sunlight and be destroyed earlier than this, perhaps with a half-life of 15 or 25 years. Yet others will be buried more deeply and will last longer, perhaps with a half-life of 100 years. This assumption would suggest that the concentration of dioxins was twice as much immediately after dumping stopped in the 1970's and will be half as much in the 2060's. Long after many of the fishermen who depend on the Galveston Bay for their livelihood will be dead, the SJRWP will still be dangerous and a source of lethal contamination to the Bay system.

In summary, it is highly unlikely that the PCDD/F concentrations found in the SJRWP will be significantly reduced in the working lifetime of a typical human. Thus the problem that existed in the 1960s and 1970s when the Champion Paper Company discharged its waste into the SJRWP is still a problem today and will be fifty years from now.

XII. DIOXIN ACCUMULATION IN MARINE ORGANISMS OF GALVESTON BAY

The Texas Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG) routinely collects fish, crabs, and other aquatic life samples from bodies of water across the state and analyzes them for various contaminants of potential public health concern. As part of this monitoring program, the Texas Department of Health (TDH – the predecessor agency for DSHS) collected fish and crab samples from the San Jacinto River, Houston Ship Channel, and Upper Galveston Bay in 1990. As a result of excessive dioxin concentrations found in these samples, TDH issued a seafood consumption advisory for catfish and blue crabs caught from these waters in September of 1990. The advisory recommended that men should consume no more than one 8-ounce meal of catfish or blue crabs from

this area per month and furthermore that women of child-bearing age and children should not consume any catfish or blue crabs from the Houston Ship Channel or the Upper Galveston Bay. Since 1990, TDH/DSHS has conducted four additional health consultations/risk characterizations for the consumption of seafood from the Houston Ship Channel and Upper Galveston Bay in 1997, 2001, 2005, 2008 and one characterization for Lower Galveston Bay in 2008. All of which recommended the continuance of the previously issued advisory on the consumption of catfish and/or blue crabs.

In July 1995, the Houston Ship Channel Toxicity Study reported unexplained, high concentrations of dioxins in sediment samples in the vicinity of the San Jacinto River where it flows under the I-10 Bridge. Section 303(d) of the Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, states must develop a total maximum daily load (TMDL) for each pollutant that has been identified as contributing to the impairment of water quality in that water body. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas. Because of the elevated levels of dioxins found in fish and crabs, the Houston Ship Channel system was placed on the §303(d) impaired surface waters list, and the TCEQ initiated a TMDL project (SJRWP 82).

In carrying out the dioxin TMDL project, the University of Houston collected hundreds of sediment, water, fish, and other aquatic life samples from 2002 through 2005 and analyzed them for various congeners of PCDDs and PCDFs (SJRWP 62). The University of Houston team obtained the following results. Tissue show dioxin concentrations between 0.4 and 41.0 ng TEQ/kg (pg TEQ/g) wet wt for catfish and between 0.4 and 16.0 ng TEQ/kg wet wt for crabs, with average values of 5.1 and 3.8 ng TEQ/kg wet wt and median values of 3.4 and 3.7 ng/kg-wet wt, respectively. Lipid-normalized concentrations (catfish samples normalized to 3% lipids and crab samples to 2% lipids) yielded median TEQ values of 8.4 and 10.5 ng/kg wet wt for catfish and crab, respectively. **It is noted that the health-based standard of 0.7**

ng/kg (EPA criterion for a human risk level of 10^{-5}) was exceeded in 94% of the catfish samples and in 90% of the crab samples. The concentrations of total PCDD/PCDF were not significantly correlated with lipid content ($p > 0.05$); correlation between 2378-TCDD and lipid content was significant for catfish even though the fit was weak ($r^2 = 0.32$). Relationships between dioxin concentrations and size and weight of the individual were also investigated but no statistically significant catfish or crab correlations were found. The concentrations for the individual dioxin congeners ranged from 0.03 to 230.0 ng/kg wet wt for catfish and from 0.1 to 260.0 ng/kg wet wt for crabs. Most of the dioxin concentration in catfish can be attributed to OCDF with an average contribution of 20% to the total PCDD/PCDF sum (only the 2378-substituted congeners), while 2378-TCDF was the major contributor (23% on average) to dioxin concentrations in crabs. In both cases, 2378-TCDD was the major contributor to the total TEQ (average contribution of 74 and 65% for catfish and crab, respectively). An important observation was the absence of high concentrations of OCDD in tissue relative to the remaining 16 congeners in contrast with what was observed in sediment samples (OCDD concentrations up to three orders of magnitude higher than those for the remaining congeners) (SJRWP 62).

Catfish and crab dioxin concentrations varied along the main ship channel. The segment 15 to 25 km in from Morgan's point, a highly industrialized part of the channel, exhibited the highest average TEQ concentration in sediment and catfish, whereas the segment between 0 and 15 km in from Morgan's Point showed the highest concentrations in crabs. While most main channel sediment concentrations were relatively low, TEQ concentrations for the San Jacinto River and two of the tributaries were notable exceptions as was station 15979. Overall, catfish TEQ concentrations were lower in the side bays than in the main channel at the confluence with the bays. TEQ concentrations in crabs also exhibited higher levels for main channel locations than those in side bays. Data suggest that spatial variability is attenuated between sediment and tissue samples, tissue samples being

much more uniform. Possible explanations include biota mobility and preferential bioaccumulation of lower chlorinated congeners.

Temporal trends in dioxin concentrations in sediment and tissue collected in this study were compared to data gathered by others between 1989 and 2001. During the 1989–2001 time period, a total of 43 sediment samples (from 17 locations) and 133 tissue samples (from 19 locations) were collected and analyzed using method EPA 1613. Sediment concentrations from this study were compared to concentrations measured in 1993, 1994, and 2001. It is noted, however, that differences in sampling and analytical methods used in the 1993–1994 study may limit the results of this comparison. The average TEQ concentration in sediment from previous studies of 37.3 ng/kg dry wt is very similar to the average TEQ measured in this study of 37.2 ng/kg dry wt

Due to the dioxin fish advisory in the channel, dioxin in tissue had been measured seven times between 1989 and 2001. In addition, two locations in the channel that are downstream of former paper mill discharges (near the San Jacinto Monument and the Lynchburg Ferry) had been monitored annually from 1992 to 2001. Historically, the highest TEQ for both catfish and crab was measured near the San Jacinto Monument. The levels of dioxins measured in tissue samples in this study are compared to their historical counterparts in Fig. 4b and c (EXHIBIT XXVII). Monitoring locations can be obtained from the map of the Houston Ship Channel and Upper Galveston Bay in EXHIBIT XXCVIII (SJRWP 62, Figure 1). The data in Fig. 4b and c were not lipid-normalized as information on percent lipids was not available from past studies. The decision not to lipid-normalize the data is also supported by the lack of correlation between lipid content and dioxin concentrations. TEQ levels in catfish measured in 2002 appear to be higher than those measured previously with the exception of stations 11252 and 13337 (Fig. 4b). The mean of the total TEQ (using data for the stations measured both in previous studies and in this study) was found to be 8.6 and 5.5 ng/kg wet wt for the previous and current studies, respectively. In contrast, concentrations in crabs from previous studies appear to be higher than those measured in this study with the exception of station 11273 (Fig.

4c). The average TEQ in crabs from previous and current studies were 3.7 and 3.9 ng/kg wet wt, respectively (SJRW 62).

EXHIBIT XXIX (SJRW 62, Figure 5) shows an analysis of temporal trends for each of the dioxin congeners in catfish at a location near the San Jacinto Monument (location showing the highest concentration of dioxins in catfish). This analysis was conducted using the data collected from 1992 and including the current study (SJRW 62). Overall, PCDDs were higher than PCDFs with 2378-TCDD showing the highest levels throughout the entire period. It can be seen from the figure that the PCDD lines remain relatively parallel from 1992 to 2002, with the exception of 123678-HxCDD, which did not follow the trend in 1998. In contrast, the PCDF lines did not follow the same trends, especially those for congeners 12378-PeCDF, 123678-HxCDF, 234678-HxCDF, 1234678-HpCDF, and OCDF, which differ substantially from the remaining curves after 1995. This may suggest a change in dioxin sources around 1995. **Data in Fig. 5 also indicate that, in general, there has been little change in congener concentrations with time. Linear regressions for each of the curves showed that, for most of the congeners the slope of the best-fit line was not significantly different from zero.** The only exceptions were the congeners 2378-TCDD, 123478- HxCDD, 123789-HxCDF, and 1234789-HpCDF, which exhibited a slightly increasing trend with time (p -values between 0.01 and 0.05 and r^2 between 0.3 and 0.5). Results from a Mann-Kendall test for this data set confirmed the results from the linear regressions. The total TEQ showed an increasing trend with time (p -value = 0.05).

As part of its routine fish consumption advisory follow-up activities for the Houston Ship Channel, San Jacinto River, and Upper Galveston Bay, Texas Department of State Health Services Seafood and Aquatic Life Group (DSHS SALG) traveled to the Houston area on four different occasions in February-April of 2004 to obtain additional fish samples. One of the sites visited was the tidal portion of the San Jacinto River immediately upstream of the I-10 Bridge. Seven fish (2 blue catfish, 2 spotted seatrout, 1 hybrid striped bass, and 2 red drum) and two blue crab specimens were collected from this location. The skin-off fish fillets were labeled,

packaged, frozen, and hand-delivered to the DSHS laboratory for analysis. The blue crab samples were prepared by removing the top shell and apron of each crab, followed by removal of gills, viscera, and eggs from the body cavity. Crabs were split along the ventral line, half of each crab was used to form a composite for the site, and composites were packaged, labeled, frozen, and hand-delivered to the DSHS laboratory for analysis. In all, 7 fish and 2 crabs were analyzed for TCDD TEQ. The blue crabs averaged a TCDD TEQ concentration of 3.107 pg/g. In the fish samples, Blue Catfish (2) averaged 6.040 pg/g; Spotted Seatrout (2) averaged 0.233 pg/g; Striped Bass (1) measured 1.541 pg/g and Red Drum (2) averaged 0.097 pg/g. In terms of a possible lifetime cancer risk only the blue catfish concentrations indicate a high increased lifetime risk for the child of a subsistence fisherman. All other fish and shellfish species showed risk factors ranging from moderate increased to no increased lifetime risk for all categories of consumers ranging from subsistence to sporadic fisherman and their children. Details are found in Table 17, Appendix C of the Public Health Assessment-San Jacinto River Waste Pits (SJRW 31)

The Texas Department of Health (TDH; now the Texas Department of State Health Services or DSHS) first issued consumption advice (ADV-3) for the Houston Ship Channel in 1990. The extant ADV-3 covered portions of the Houston Ship Channel and all contiguous waters downstream of the Lynchburg Ferry crossing – including tidal portions of the San Jacinto River and Tabbs Bay – where catfish and blue crab samples were found contaminated with dioxin. The latest survey of the area by DSHS was conducted in 2004.

With input from the Galveston Bay Estuary Program (GBEP) Seafood Safety Task Force, a team from the DSHS SAL group selected five sites to provide coverage of the study area. These included a site near the Houston Yacht Club in UGB (Site 1); one near Morgan's Point in Tabbs Bay (Site 2); a site within the HSC near the Lynchburg Ferry crossing (Site 3); the tidal portion of the San Jacinto River immediately upstream of IH-10 (Site 4); and the HSC turning basin (Site 5). A map in EXHIBIT XXX (SJRW 33, Appendix 1) shows the chosen sites. The SALG field team made four sampling trips in early 2004 (February and March-April) to collect fish and blue

crab tissue samples from the previously designated sites. The field team set five to seven gill nets (125 to 300 feet in length) and seven to eight baited crab traps (bait for crab traps was obtained from non-game fish caught in gill nets) at each site.

Polychlorinated dibenzo-p-dioxins and/or polychlorinated dibenzofurans (PCDDs/PCDFs – dioxin) were detected in 28 of 35 fish at concentrations ranging from 0.092 pg/g to 8.895 pg/g (see EXHABIT XXXI, SJRWP 33, Tables 4a and EXHIBIT XXXII, SJRWP 33, Table 4b) and in all 10 blue crab samples. The single southern flounder collected (Site 1) in 2004 did not contain detectable levels of dioxin, nor did the one channel catfish (Site 3) collected during the present survey contain dioxin. Not all congeners of PCDDs/PCDFs were contained in all samples. Before generating summary statistics, dioxin and furan congeners were converted to concentrations equivalent in toxicity (TEQs) to that of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD; see method section for details). Risk assessors generated summary statistics on TEQ concentrations in each species collected at each sampling site (Tables 5a, 5b). All blue catfish (10/10) contained PCDD/PCDF congeners, as did hybrid striped bass (2/2), common carp (2/2), smallmouth buffalo (3/3), and the single white bass collected. Four of six spotted seatrout, four of five black drum, and two of four red drum contained measurable dioxin equivalents. Blue catfish had the highest average concentration of dioxin equivalents (3.7 ± 3.1 pg/g), followed by smallmouth buffalo (2.27 ± 1.2 pg/g). Blue crabs contained an average of 2.03 pg/g dioxin equivalents. At 0.11 (± 0.03) pg/g, red drum contained the lowest concentrations of dioxin equivalents. Dioxin equivalent concentrations increased from Site 1, with an average concentration of 0.56 ± 0.7 pg/g to Site 5 (HSC turning basin) where the average concentration was the highest (2.89 ± 2.3 pg/g).

To reiterate, twenty-eight of 35 fish and all blue crabs collected from the HSC-UGB system in 2004 contained polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. Dioxins were highest in blue catfish, followed by smallmouth buffalo, blue crabs, hybrid striped bass, and common carp. All other species contained lower levels of dioxin. Dioxin exceeded the health-based assessment comparison (HAC) value in fish other than spotted seatrout collected at the San

Jacinto River site and at the HSC turning basin. Dioxin concentration in spotted seatrout, while present, did not exceed the HAC for dioxin. Dioxin in blue crabs collected at Morgan's Point in Tabbs Bay slightly exceeded the HAC for dioxin, as indicated by the hazard quotient of 1.04, and in the two blue crab samples from the tidal portion of the San Jacinto River near I-10. Although dioxin concentrations in blue crabs from the HSC and UGB may have decreased since the last time DSHS surveyed these contaminants in 1996, conclusions to this effect are premature – primarily because fluctuations in estuary environmental conditions could influence concentrations of dioxin in samples from this complex system due to the mobility of fish and shellfish in estuary systems. Dioxin in blue crabs from Site 2 (Morgan's Point in Tabbs Bay) and Site 4 (tidal portion of the San Jacinto River near I-10) exceeded the HAC value for this contaminant. These findings contribute to an overall hazard index for blue crabs that approaches 1.0. Thus, the DSHS concludes that consumption of blue crabs from waters covered by the present (2004) survey continues to pose a hazard to human health.

In 2006 and 2007 fish and crabs were collected and analyzed from both upper and lower Galveston Bay by the Texas SHSD Policy, Standards, and Quality Assurance Unit Seafood and Aquatic Life Group (SJRWP 87 and SJRWP 88). Testing was done at several locations in each. The results from Upper Galveston Bay for the presence of PCCD and PCCF are shown in EXHIBIT XXXIII, (SJRWP 87, Table 5). A map of the five sample locations is shown in EXHIBIT XXXIV (SJRWP 87, Fig. 1). The equivalent test results for Lower Galveston Bay are shown in EXHIBIT XXXV (SJRWP 88, Table 5) with a map of the test location sites in EXHIBIT XXXVI (SJRWP 88, Fig. 1).

In summary, all of the studies that tested for the presence of PCCDs and PCCFs in fish, crabs and clams from the Galveston Bay System found evidence of contamination. The actual concentrations of the various congeners varied little over time since 1992. In general though the concentrations of the various congeners as well as the overall level of the TEQ as measured in catfish at the San Jacinto monument did not significantly change over the period from the beginning of testing in the early 1990s to the tests conducted

beyond the middle of the 2000s. The overall level of dioxins in fish and crabs varied somewhat depending on the research group doing the testing, the location of the test, and the species of fish tested. Higher levels of dioxins were found in catfish in general. Geographically, the highest tissue TEQ (pg/g) were found in the San Jacinto River near I-10 (closest to the SJRWP). In general though all sampled species showed higher contamination at locations nearer the Tidal portion of the San Jacinto River and the Houston Ship Channel. Lower contamination levels were found at locations farthest away from these areas and in the lower reaches of Galveston Bay. The majority of tissue samples tested contained dioxin levels higher than the health-based standard of 0.7 nag/kg (EPA criterion for a human risk level of 10^{-5}).

XIII. DIOXIN FINGERPRINTING—WASTE PIT, GALVESTON BAY—HOUSTON SHIP CHANNEL SEDIMENT—BAY SYSTEM BIOTA (FISH AND CRABS).

Dioxin is a general term applied to a group of compounds consisting of 75 polychlorinated dibenzo-p-dioxins (PCDDs) and 135 polychlorinated dibenzofurans (PCDFs). They are structurally very similar, differing in the number and spatial arrangement of chlorine atoms in the molecule. The dioxins and furans are different in that the parent chemical unit contains two or one oxygen atom, respectively. These chemicals have no known function and are not manufactured except for research purposes. They are however produced as non-intentional byproducts of certain industrial processes, particularly combustion (SJRWP 1) and the manufacture of chlorinated pesticides and chlorine bleaching processes (paper mills).

Dioxins are very environmentally persistent with half-lives ranging up to 100 years in the absence of sunlight and certain bacteria. They can be transported long distances from their source by air and water as well as in organic waste and soil.

Many of these compounds are extremely toxic and bio-accumulative. They are mutagenic, linked to the suppression of the human immune system and carcinogenic. In humans they have a half-life of about 7 years (about the same time as for one's somatic cells to be replaced). Their half-life in organisms varies from organism to organism but can never the less accumulate for several years in fatty tissue. The toxicity of the congeners differs from

one to another. Seventeen of the congeners are particularly toxic. Their relative Toxic Equivalency Factors are listed in EXHIBIT XXXVII (SJRW 31). This table shows that the most toxic congener is 2,3,7,8-TCDD (TEF=1) followed by 2,3,4,7,8-PeCDF (TEF=0.5) and 1,2,3,7,8-PeCDD (PeCDD). The least toxic are OCDD and OCDF (TEF=0.0001). For example this means that a concentration of 1 unit of 2,3,7,8-TCDD has the same toxicity as 10,000 concentration units of OCDD. The others fall in between these extremes. Note that the mono, di and tri congeners are not listed, nor do they usually appear as contaminants. Otherwise, toxicity decreases roughly an order of magnitude per chlorine atom with decreasing number of chlorine atoms in the molecule. This fact indicates that different sources of dioxins can have vastly different toxicity per unit weight depending on the congener composition. At a particular site, the dioxin concentrations, rather than being given in weights per congener are designated in units of TEQ (pg/g or ng/kg). This designation is for the total Toxic Equivalents of dioxin and is a measure of its human toxicity rather than quantity. Here

$$TEQ = \sum C_i (TEF)_i$$

The sum is over all congeners and TEQ is defined as the Toxicity Equivalent. The toxic equivalent of a group of congeners would be the same as the toxic equivalent weight of only 2,3,7,8-TCDD.

Many of the studies concerning dioxins in the Galveston/HSC system report dioxin concentrations in terms of TEQ. This is useful if one is interested in the toxicity of the site or the biota involved, but it is not informative when asking what the source of the dioxin might be. This is because the source most probably has a characteristic set of weight ratios for certain congeners. One source that does report specific quantities of congeners at the various experimental sampling sites is a study prepared for the McGinnes Industrial Maintenance Corporation, the International Paper Company and the U.S. Environmental Protection Agency, Region 6 (SJRW 58). This report studied a variety of sediment areas as well as clams found at these areas. The report was wide spread, studying sites throughout the upper Galveston Bay near the mouth of the San Jacinto River (including the SJRW) and the Houston Ship Channel. They reported that dioxins were found in sediments throughout the entire system with strong, rather equal, concentrations of dioxins except for the waste pit where the value of TEQ was orders of magnitude higher than anywhere else. They find that the fingerprint of these sediment dioxins was fairly uniformly characteristic and different from that of the dioxins in the waste pit. Modeling the data led them to believe

that there were two populations of dioxins that they labeled EM1 and EM2 for end member 1 and end member 2. The relative values of the various congeners of EM1 and EM2 are pictured in EXHIBIT XXXVIII (SJRW 58, Figure 6-26). Note that EM 1 is predominately composed of the dioxin OCCD and EM 2 is predominately 2,3,7,8-TCDF and 2,3,7,8-TCDD. The report presents data for the dioxin concentrations in clams and sediment in eight transects in the vicinity of the waste pit. EXHIBIT XXXIX (SJRW 58, Fig 6-20a) graphically shows the results of analyses along the transect SJTTR1. Its location is indicated in the insert in the upper right corner of the diagram. The fractional amounts of the various dioxin congeners for the sediment samples in the transect as well as their location are shown on the left hand portion of the figure. Those for the clam samples are shown on the right and bottom. Notice that the sediment graph is very similar to that for EM 1 in EXHIBIT XXXVIII. In fact a modeling analysis indicates the sediment to be composed of approximately 98% EM-1 and 2% EM-2. The clam values appear to be a mixture of almost equal amounts of EM-1 and EM-2. EXHIBIT XXXX (SJRW 58 Fig 6-20b) shows similar results for the transect SJTTR3 which is located on the waste pit. Both the pictured clam and sediment samples appear to be almost exclusively EM-2. EXHIBIT XXXXI (SJRW 58 Fig 6-29) graphically depicts the calculated fraction of EM-1 and EM-2 in all of the samples taken within the preliminary site perimeter of the SJRW area of concern. Most but by no means all of the data from the waste pit itself is designated EM-2 while most of the data from the sediment under the surrounding water is designated EM-1. A conclusion reached in this report is that there are two sources of dioxin, one that is confined to the waste pit and one that is deposited everywhere else. The suggestion is that the waste pit is not leaking and the majority of the dioxin found in the Galveston Bay System comes from some other source or sources. Combustion residue, air-borne particles, precipitation runoff, industrial sources along the ship channel.

One major question is, if the dioxins that the clams are subjected to is almost exclusively EM-1, why do they show internal concentrations of dioxin that are indicative of the ingestion of dioxins of the type EM-2? Since all other suggested sources are considered to be composed primarily of EM-1, what is the dioxin source feeding the biota? It would appear to be only the San Jacinto River Waste Pit. Thus it does not seem to matter where the sediment dioxins come from, what the clams are ingesting is from the waste pit. However, if that is the case, how do the clams obtain it? They cannot go to the waste pit and it is suggested that the pit does not come to them. But then, perhaps it does.

The same pattern of high OCDD dioxins in the sediment and high TCDD and TCDF in fish and clams was observed by the University of Houston study group (SJRWP 62). In a very complete study of the Houston Ship Channel and the upper Galveston Bay System they found sediments that were rich in OCDD and fish and crabs that had accumulated TCDD and TCDF. This is very well shown for fish in EXHIBIT XXXXIIA and for crabs in EXHIBIT XXXXIIB. Both figures are superpositions of parts of Figure 2 of SJRWP 62 where a composite of dioxin concentrations from each animal type is superimposed and compared with a composite of dioxin concentrations from the sediment samples. Both fish and crab dioxin tissue concentrations are within an order of magnitude except for the OCDD, 1,2,3,4,6,7,8-HpCCD and OCDF concentrations. These are the predominate peaks in EM-1 as derived in JSRWP 58 and shown in EXHIBIT XXXVIII. What is left unaccounted for as EM-1 bears a strong resemblance to the congener distribution EM-2 as found in the SJRWP (seem for example, EXHIBIT XXXX).

In a very complete toxicological profile of dioxins, the U.S. Department of Health and Human Services reports that CDDs can be found in both the vapor and particle-bound phases with the low vapor pressure of OCDD resulting in its enrichment in the particulate phase in the atmosphere. When this particulate matter is deposited on water, OCDD-enriched sediments will result. The less chlorinated CDD congeners (TCDD and PeCDD) occur in greater proportion in the vapor and dissolved phases of air and rain, whereas the more chlorinated congeners (HpCDD and OCDD) are associated with the particulate-bound phases (SJRWP 24). Thus, if particles from the waste pit were to move into the water as particles, there would be a tendency for the TCDD to partition into the water phase while the OCDD would remain absorbed on the particles. This would result in OCDD enriched sediment when the particle finally settles and a TCDD and PeCDD enriched water phase. This process could continue cyclically as the sediment is washed around by currents and wind, particularly during times of high turbulence such as storms, floods or high tides. Since the OCDD is particularly strongly absorbed onto the sediment particles, they could pass through fish, crabs and clams without being retained.

This idea of phase partition is supported by the study from the U.S. Department of Health and Human Services (SJRW 24). They have found that most of the CDDs entering surface waters are associated with particulate matter and eroded soil particulates contaminated with CDDs. In the aquatic environment, significant partitioning of CDDs from the water column to sediment and suspended particulate organic matter can occur. Dissolved CDDs will partition to suspended solids and dissolved organic matter (detritus, humic substances) and are likely to remain sorbed once in the aquatic environment. From suspended sediment and water data collected from the Niagara River on the New York-Canada border, it was found that CDDs were strongly associated with suspended sediment. Concentrations of total TCDDs, PeCDDs, HxCDDs, HpCDDs, and OCDD in raw water ranged from below detection limits to 3.6 pg/L (3.6 ppq), while the concentration of these same homologue groups in suspended sediments ranged from below detected limits to 228 pg/g (SJRW 24).

It seems quite logical to consider the question of whether the majority of the sediment dioxin levels are consistent with two dioxin sources. One conclusion is that both sources are the same, namely the SJRW, and that the apparent two sources is due to two methods of transport and retransport as they move out of the SJRW and find their way to the sediment. CDDs are characterized by low water solubilities and high lipophilicities. The water solubility of 2,3,7,8-TCDD ranges from 7.9×10^{-6} to 33.2×10^{-4} mg/L. Water solubility at 25°C for the congener groups have been estimated as follows: MCDD, 0.278–0.417 mg/L; DCDD, 3.75×10^{-3} – 1.67×10^{-2} mg/L; TrCDD, 4.75×10^{-3} – 8.41×10^{-3} ; TCDD, 7.9×10^{-6} to 6.3×10^{-4} mg/L; PeCDD, 1.18×10^{-4} mg/L; HxCDD, 4.42×10^{-6} mg/L; HpCDD, 2.4×10^{-6} – 1.9×10^{-3} mg/L; and OCDD, 0.1×10^{-9} – 7.4×10^{-8} mg/L (SJRW 56). K_{ow} values range from 10^4 to 10^{12} for MCDD through OCDD, with K_{ow} values increasing relative to increasing chlorination. Because of these physicochemical properties, CDDs are expected to adsorb to bedded and suspended sediments and to bioaccumulate in aquatic organisms. The

bioconcentration factor (BCF) is the ratio of the concentration of CDDs in an organism over the concentration of CDDs in water. The BCF values for CDDs can be estimated from their K_{ow} values. Measurements of the bioconcentration of CDDs tend to increase with the degree of chlorination up to TCDDs, and then decrease as chlorination continues to increase up to the OCDD congener. The more highly chlorinated congeners, such as OCDD, appear to have the lowest bioconcentration potential either because they are less bioavailable because of their rapid adsorption to sediment particles or because their large molecule size may interfere with transport across biological membranes (SJRWP 24).

In summary, all of these data are consistent with the idea of a single source of dioxins (the SJRWP) to both sediment and biota throughout the Galveston Bay Complex. Even if there are multiple sources, the division of these sources into two components (EM-1 and EM-2) does not change the fact that the marine biota accumulate TCDD rather than OCDD and that the TCDD must come from the source that contains it. And that is the San Jacinto River Waste Pit. In fact, the high concentrations of OCDD in the sediment suggests that this process has been taking place for decades in order to accumulate the high OCDD concentrations from a source that has very little of it. The San Jacinto River Waste Pit has indeed been the source of dioxins for half a century.

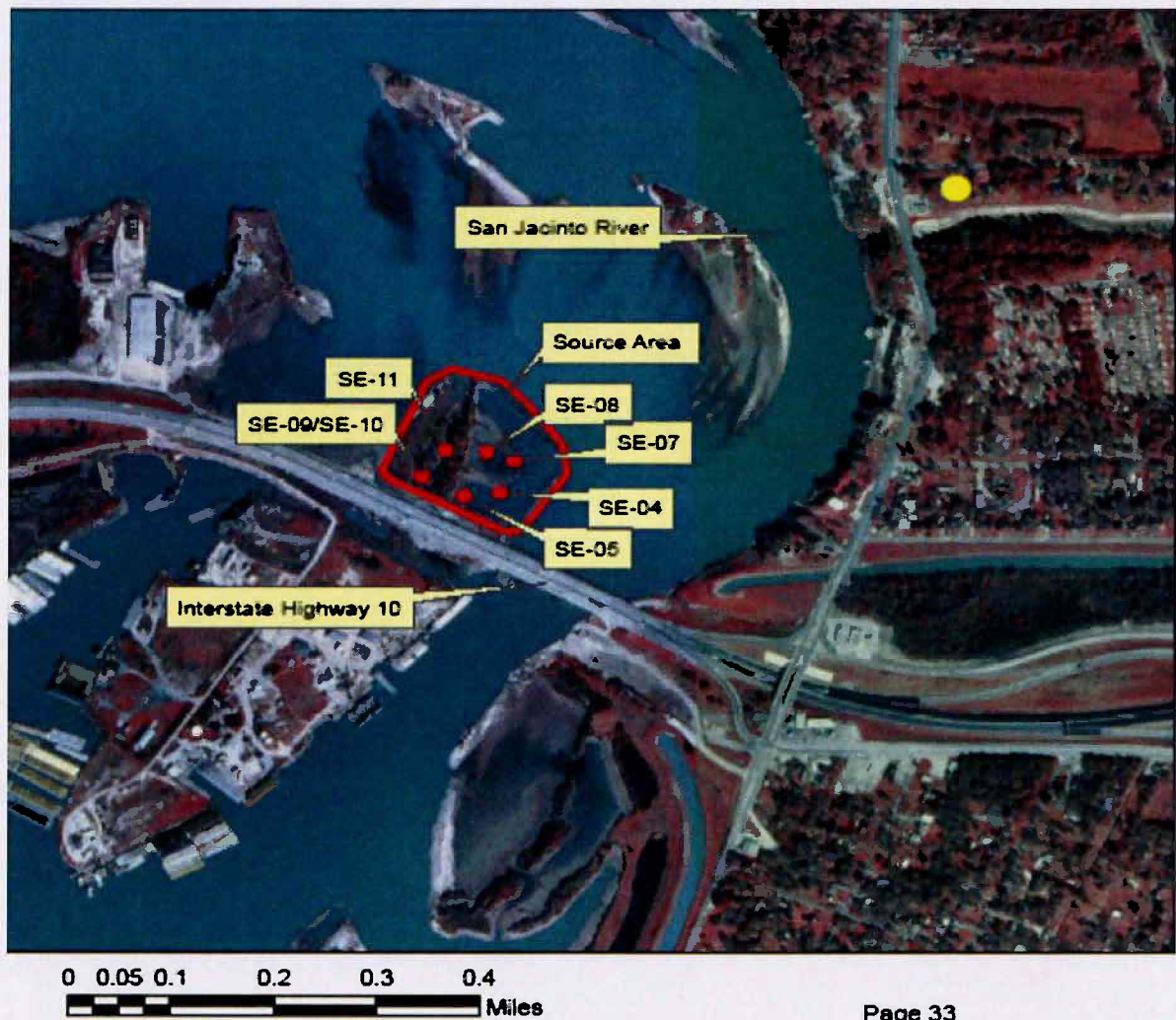
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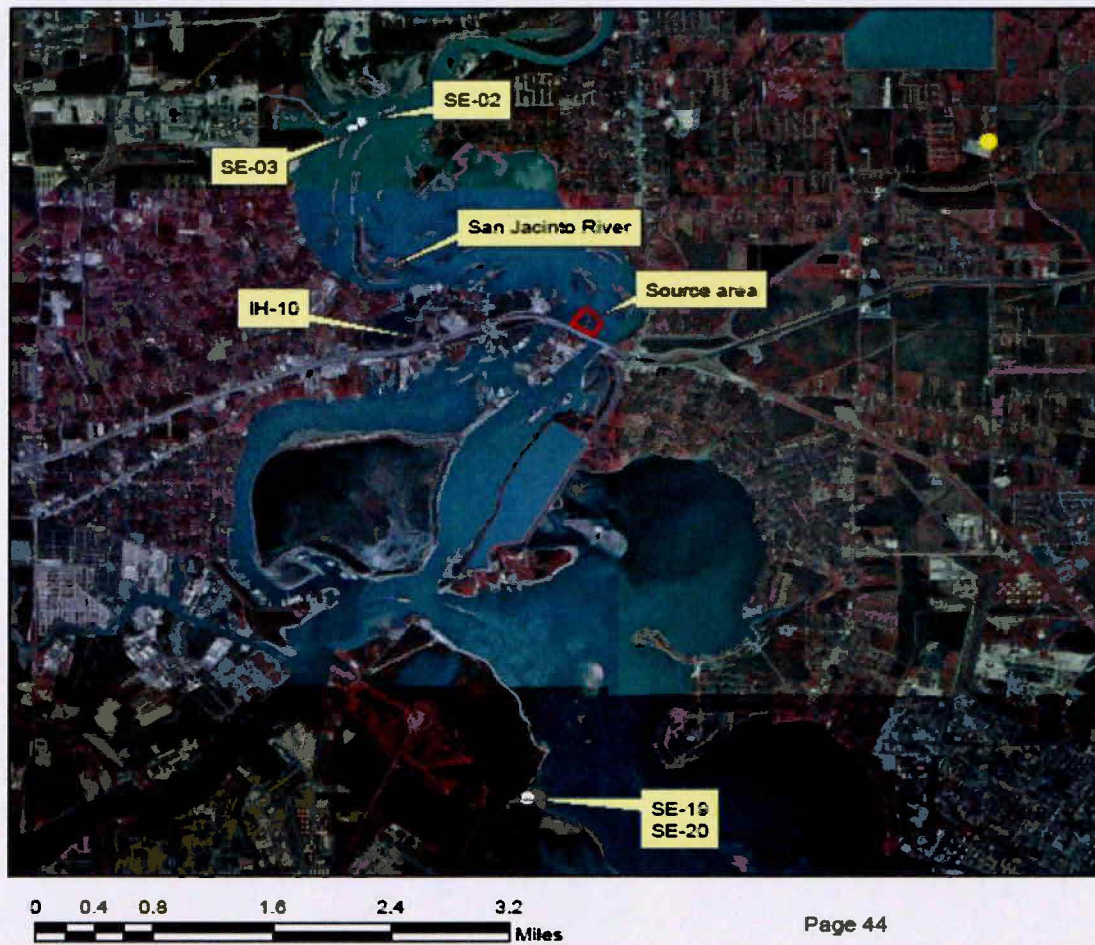
EXHIBIT I.



Page 33

Aerial Photo of San Jacinto River Waste Pits, Sediment Sample Locations (SJRWP 31)

EXHIBIT II



Aerial Photo, San Jacinto River Waste Pits, Background Sample Locations (SPRWP 31)

EXHIBIT III

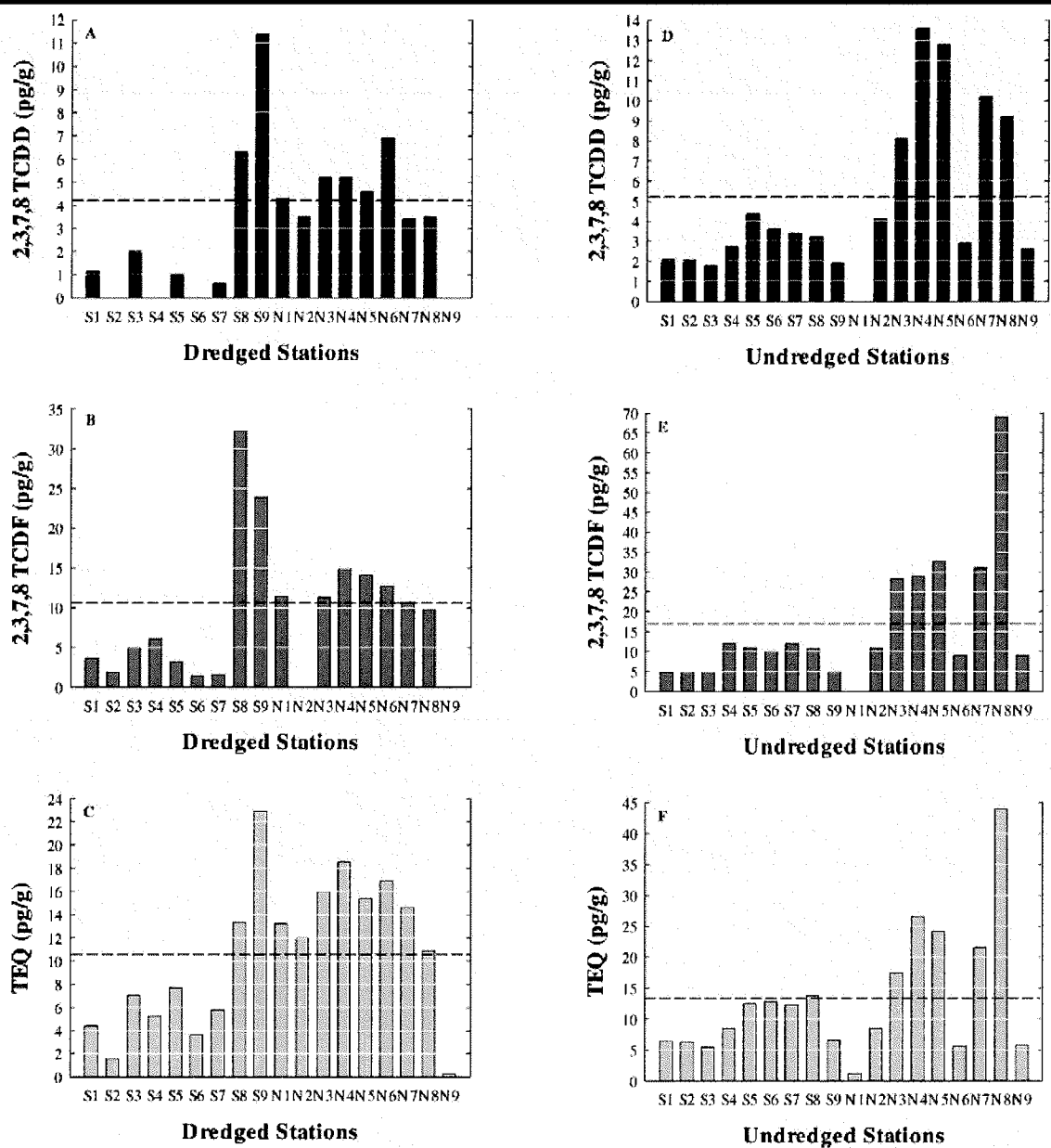
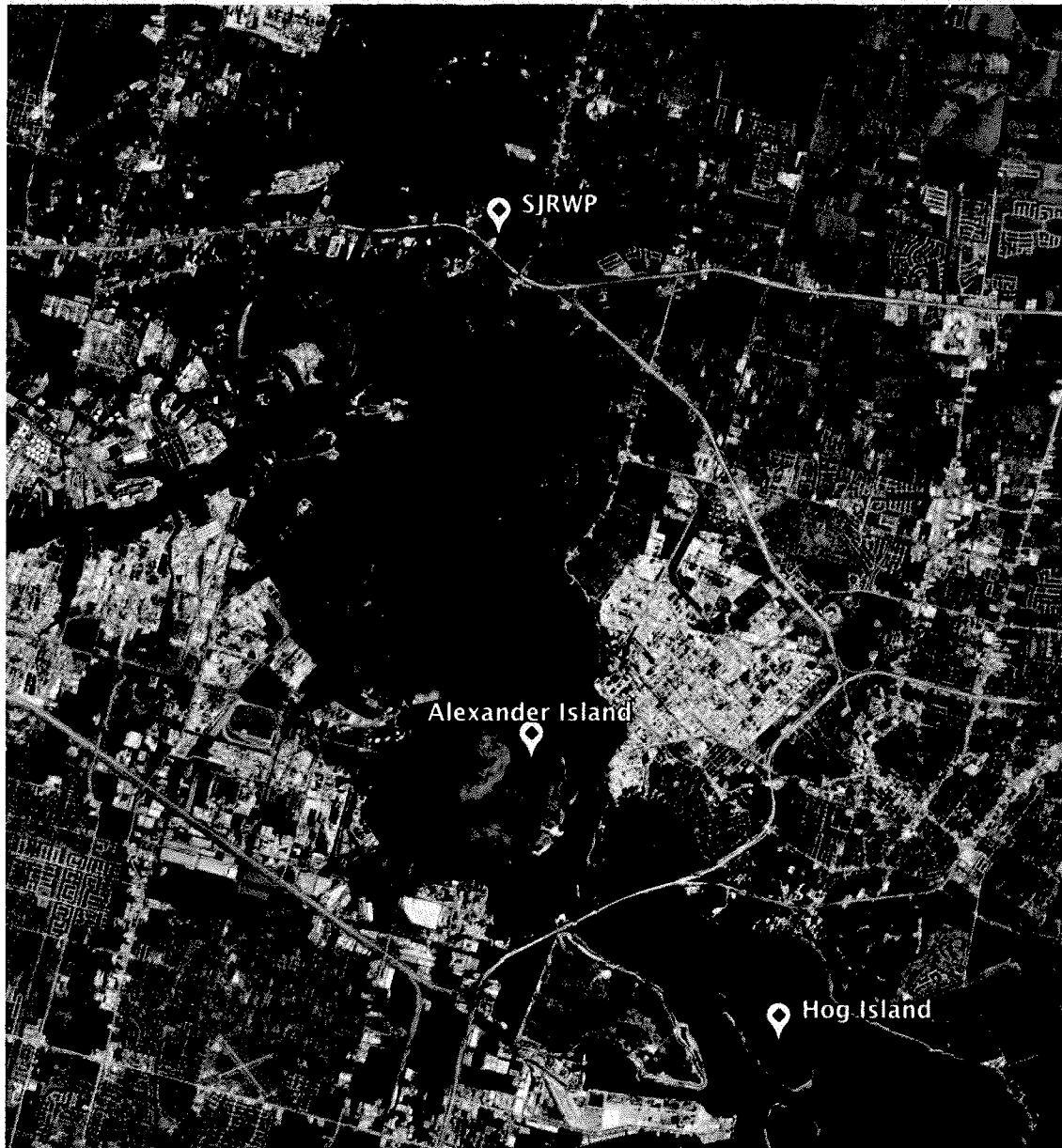


Figure 2. Concentrations of 2,3,7,8-TCDD (black), 2,3,7,8-TCDF (dark gray), and TEQ (gray) for stations along both transects (S and N denote stations from the southern [Hog Island] and northern [Alexander Island] transects, respectively). Dashed lines indicate population means, which do not include nondetects, or NDs (in pg/g, A = 4.22; B = 10.24; C = 10.52; D = 5.21; E = 17.30; F = 13.30). Missing data in panels A, B, D, and E represent NDs.

EXHIBIT IV.



Houston Ship Channel study areas, primary dredged channels and undredged channels around Alexander and Hog Islands. Dredged channels are to the west of Hog Island and to the east of Alexander Island.

EXHIBIT V

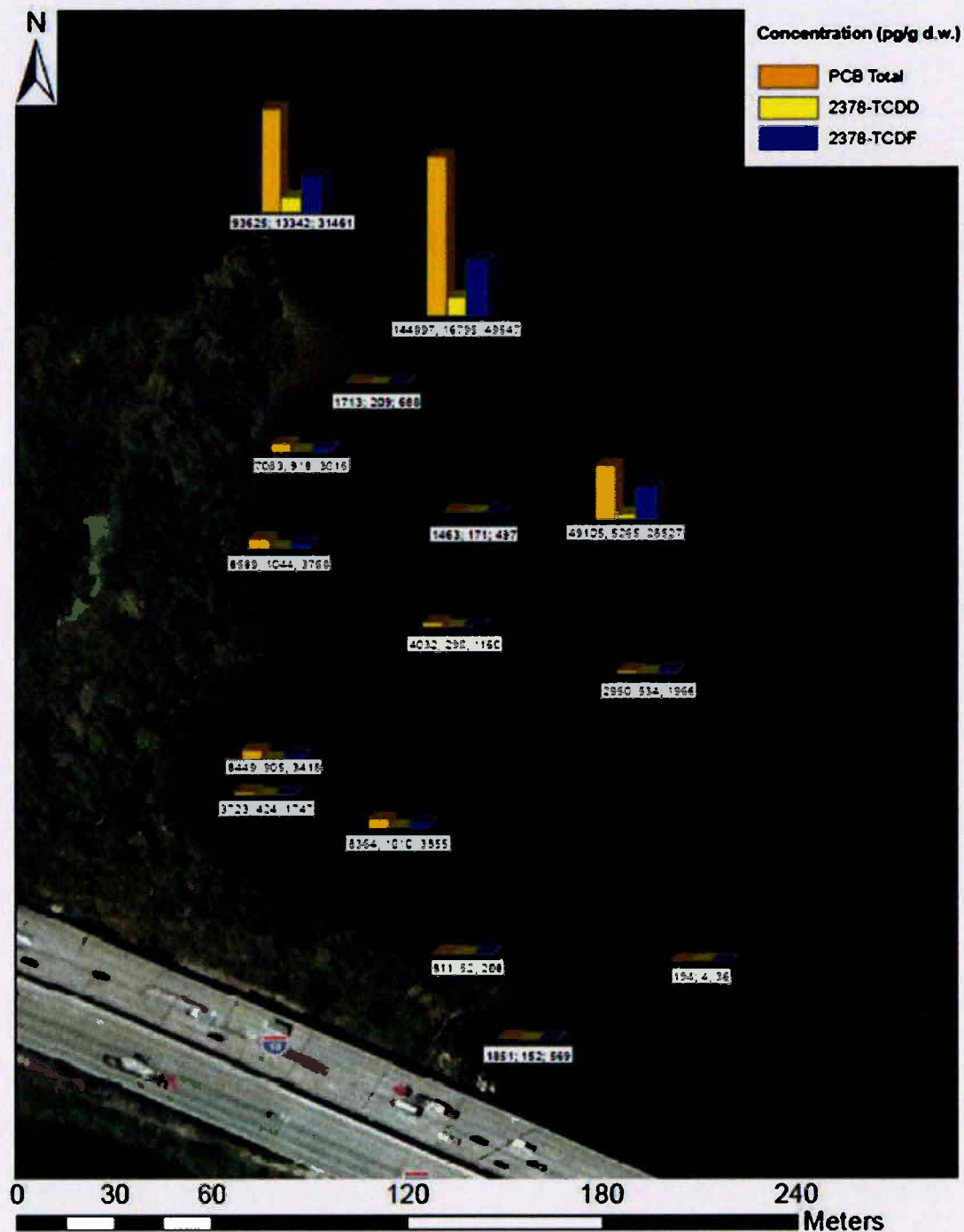
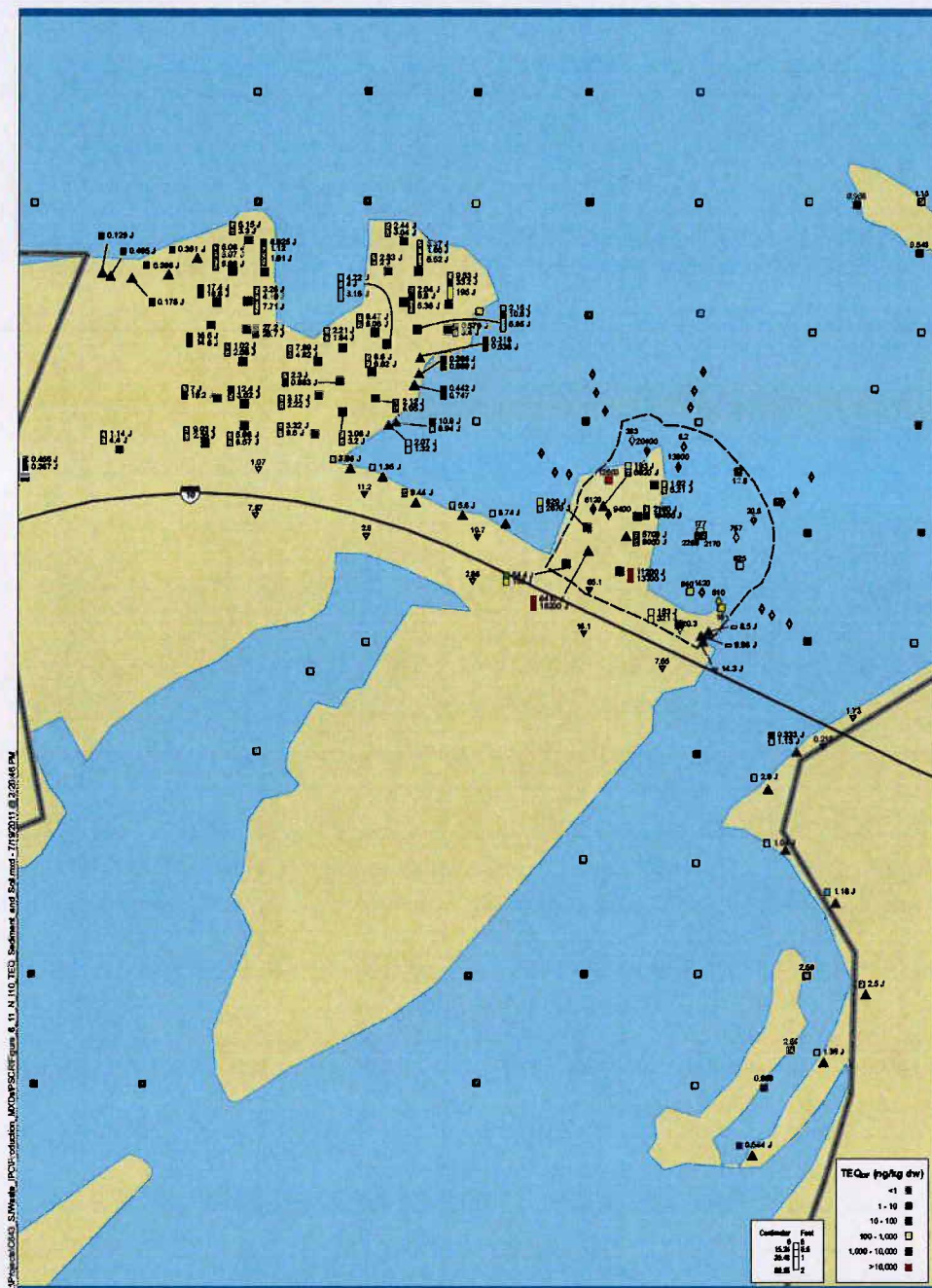


Figure 7. Surficial sediment concentrations (pg/g dw) of 2,3,7,8-TCDD, 2,3,7,8-TCDF, and Σ PCBs collected at the San Jacinto River Waste Pits, Texas, in August 2010.

EXHIBIT VI



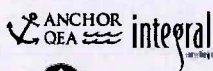
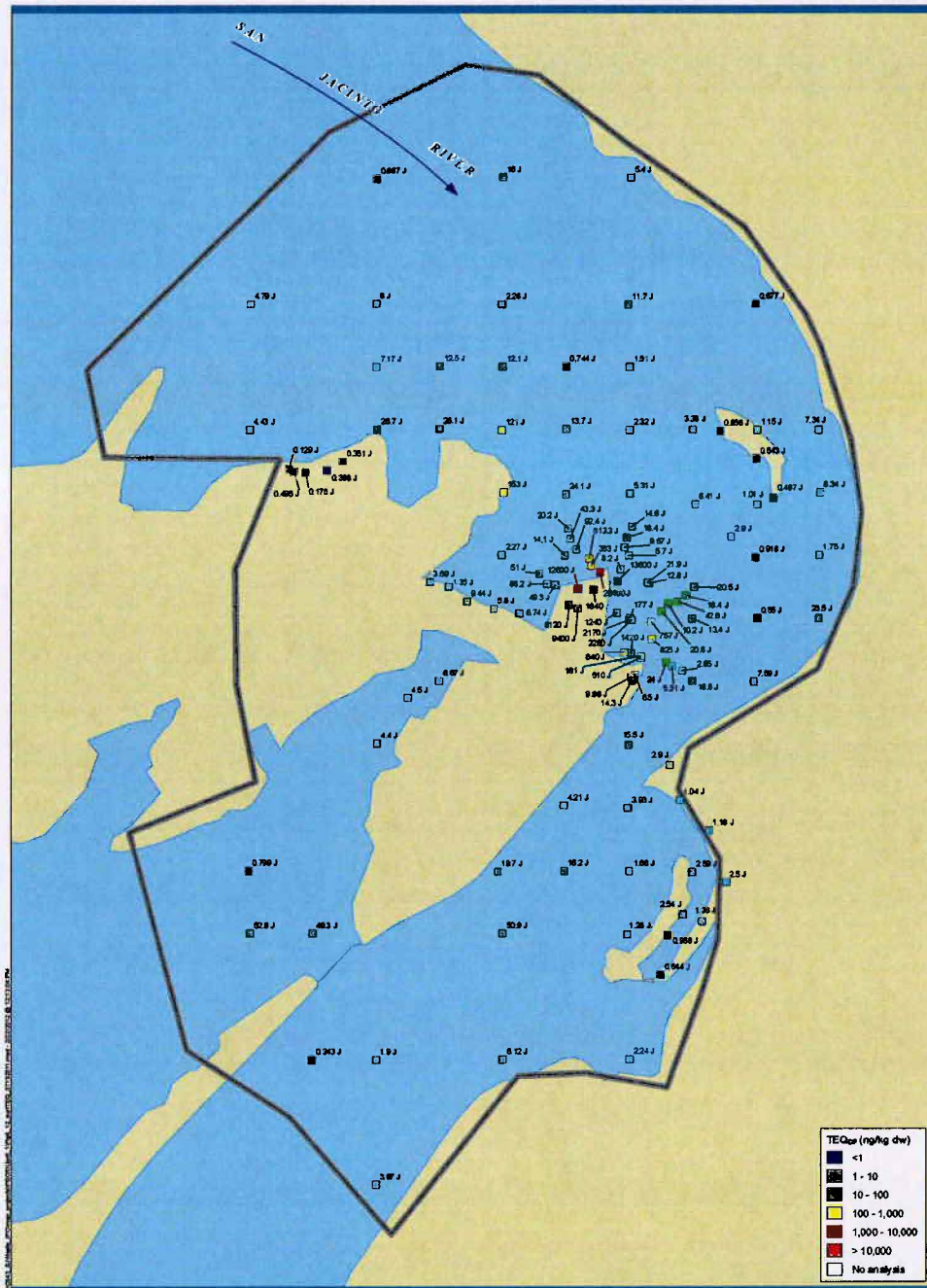
US EPA's Preliminary Site Perimeter
Original (1996) Perimeter of the Northern Impoundments
Core Location (Sediment)
Core Location (Soil)

RI Sediment Station
TORA Sediment Station
TORA Soil Station

Notes:
TEQs = toxicity equivalent for dioxins and furans
using mammalian TEFs from van den Berg, et al. (2006) (non detect = 1/2 detection limit)
J=Estimated. One or more congeners used to calculate the TEQs was not detected.

Figure 6-11
TEQ Concentrations (ng/kg dw)
in Intertidal Sediment and Soil Samples
SJRWP Preliminary Site Characterization Report
SJRWP Superfund/MIMC and IPC

EXHIBIT VII



UGEP's Preliminary Site Perimeter



Note: TEQ_{dw} = toxicity equivalent for dioxins and furans using maximum TEFs from van den Berg, et al. (2003) (non detect = 12 detection limit)
J = Estimated. One or more congeners used to calculate the TEQ_{dw} was not detected

Figure 6-12
TEQ_{dw} Concentrations (ng/kg dw)
in Surface Sediment
SIRWP Preliminary Site Characterization Report
SIRWP Superfund/MIMC and IPC

EXHIBIT VIII

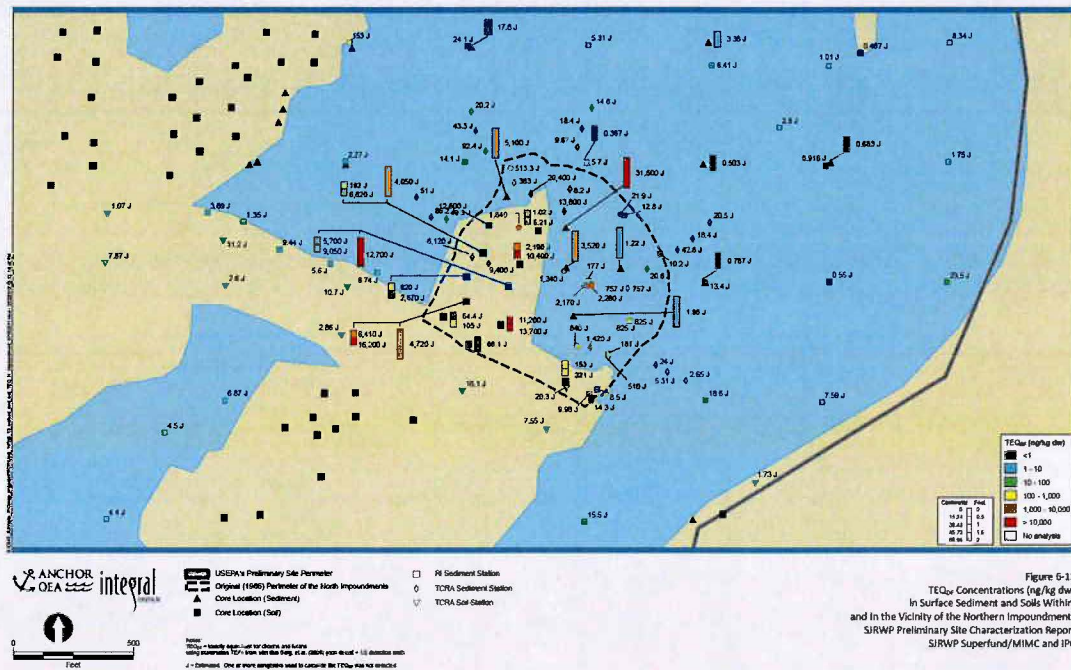


Figure 5-13
TEQ Concentrations (ng/kg dw)
in Surface Sediment and Soils Within
the Vicinity of the Northern Impoundments
SIRWP Preliminary Site Characterization Report
SIRWP Superfund/MIMC and IPC

EXHIBIT IX

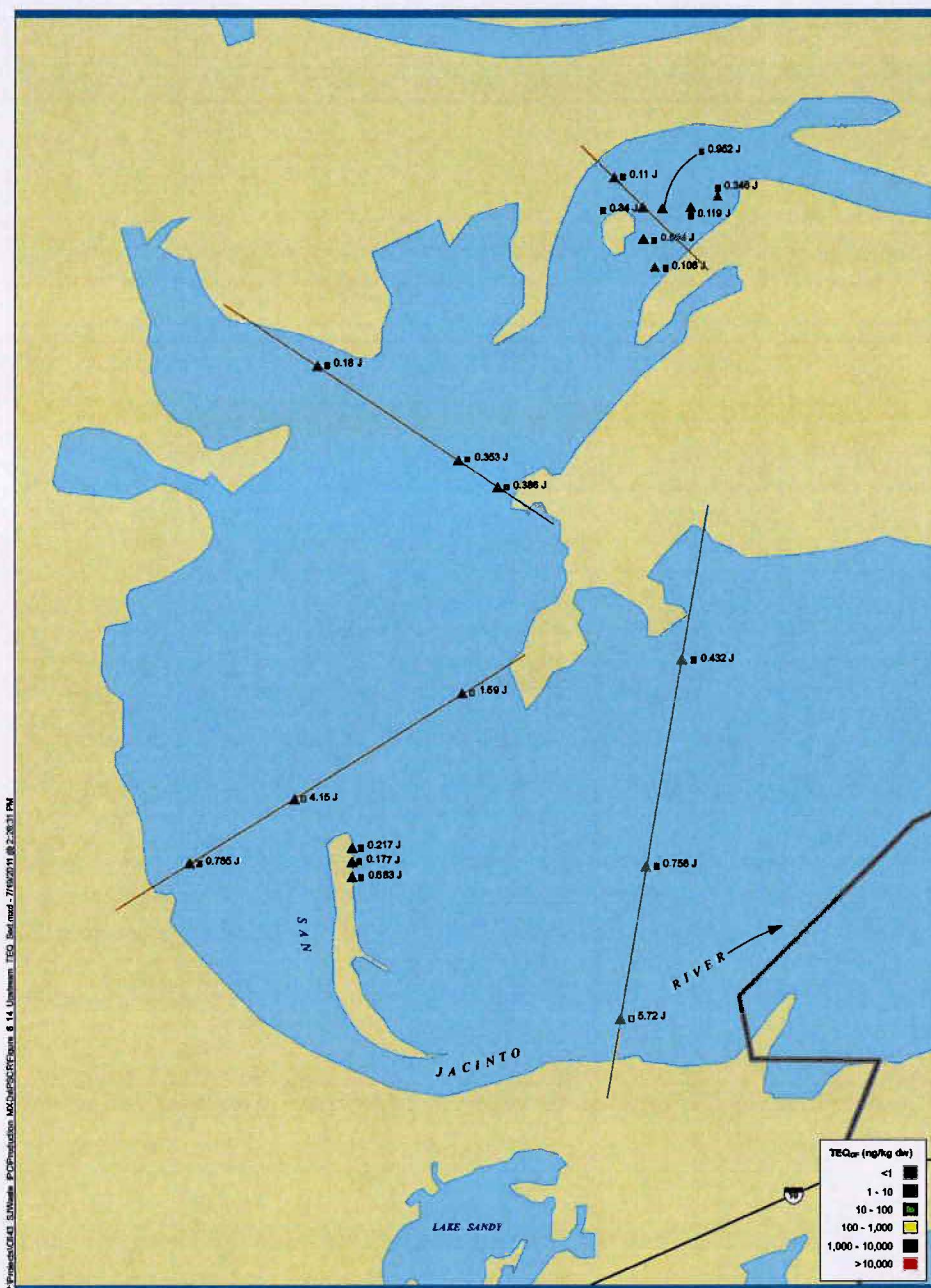


Figure 6-14
TEQ_{OC} Concentrations (ng/kg dw) in Surface Sediments
Upstream Background
SIRWP Preliminary Site Characterization Report
SIRWP Superfund/MIMC and IPC

EXHIBIT X

Table 6-3
Summary Statistics for Dioxin and Furan Concentrations in Surface Sediment Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
2,3,7,8-TCDD	ng/kg	120	92	77%	0.34	15,400	444
1,2,3,7,8-PeCDD	ng/kg	120	31	26%	0.0769	133	5.93
1,2,3,4,7,8-HxCDD	ng/kg	120	35	29%	0.066	2.54	1.38
1,2,3,6,7,8-HxCDD	ng/kg	120	65	54%	0.14	18.3	1.68
1,2,3,7,8,9-HxCDD	ng/kg	120	63	53%	0.109	4.85	3.50
1,2,3,4,6,7,8-HpCDD	ng/kg	120	116	97%	0.921	290	31.8
OCDD	ng/kg	120	118	98%	19.4	4,870	826
2,3,7,8-TCDF	ng/kg	120	115	96%	0.25	41,200	1,410
1,2,3,7,8-PeCDF	ng/kg	120	65	54%	0.118	8,880	114
2,3,4,7,8-PeCDF	ng/kg	120	61	51%	0.0362	3,360	56.9
1,2,3,4,7,8-HxCDF	ng/kg	120	84	70%	0.0673	9,650	150
1,2,3,6,7,8-HxCDF	ng/kg	120	64	53%	0.0768	1,790	32.4
1,2,3,7,8,9-HxCDF	ng/kg	120	16	13%	0.0963	80.7	6.23
2,3,4,6,7,8-HxCDF	ng/kg	120	36	30%	0.0471	478	9.87
1,2,3,4,6,7,8-HpCDF	ng/kg	120	106	88%	0.138	1,000	32.0
1,2,3,4,7,8,9-HpCDF	ng/kg	120	39	33%	0.117	364	11.6
OCDF	ng/kg	120	110	92%	0.266	650	46.8
TEQ _{DF}	ng/kg	120	120	100%	0.129	20,400	634

Notes

Mean calculations include detected and nondetected values. Nondetected values were set to one-half the detection limit.

Centimeter	Foot
0	0
30.48	1
60.96	2
91.44	3
121.92	4
152.40	5

EXHIBIT XII

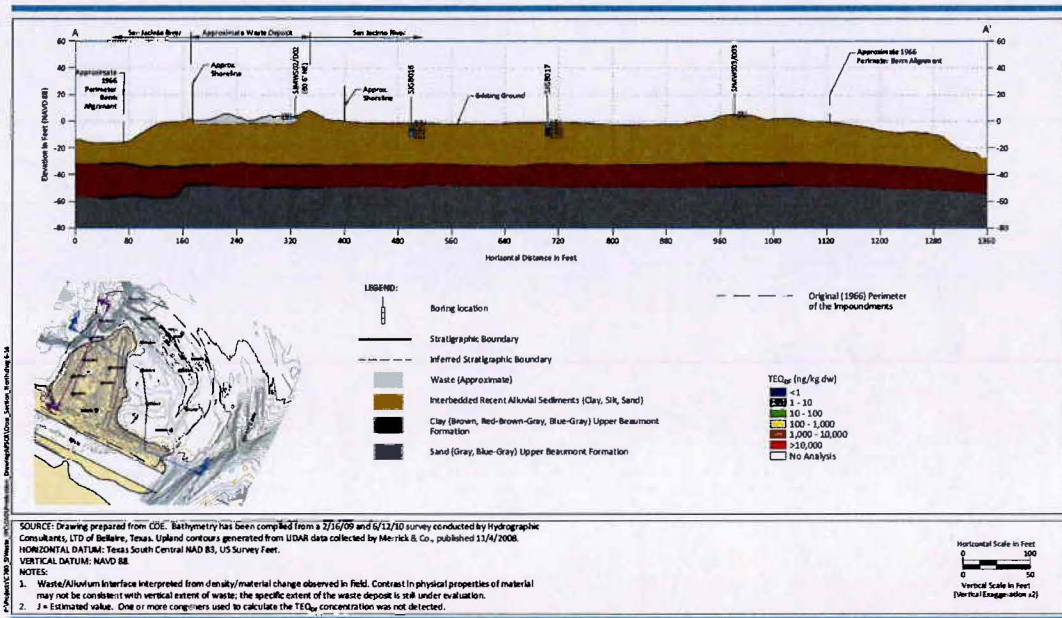


EXHIBIT XIII

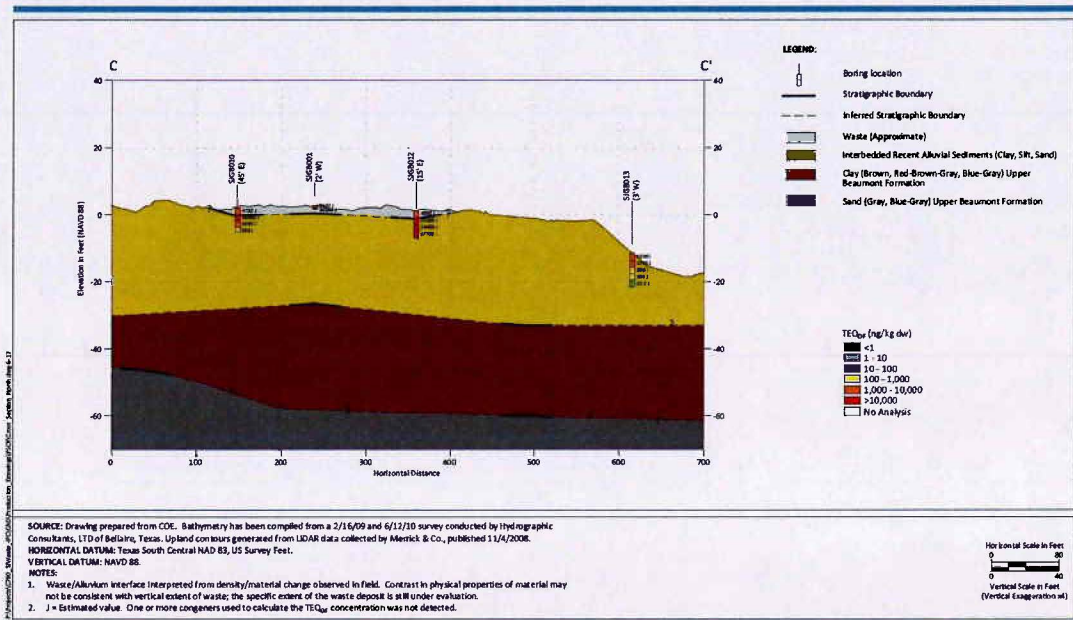


EXHIBIT XIV

Table 6-10
Summary Statistics for Dioxin and Furan Concentrations in Subsurface Sediment Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
2,3,7,8-TCDD	ng/kg	124	63	51%	0.237	18,800	959
1,2,3,7,8-PeCDD	ng/kg	124	44	35%	0.0614	134	6.61
1,2,3,4,7,8-HxCDD	ng/kg	124	43	35%	0.0833	2.08	0.260
1,2,3,6,7,8-HxCDD	ng/kg	124	80	65%	0.0656	14.3	1.17
1,2,3,7,8,9-HxCDD	ng/kg	124	84	68%	0.0984	4.95	0.868
1,2,3,4,6,7,8-HpCDD	ng/kg	124	123	99%	0.494	252	31.8
OCDD	ng/kg	124	124	100%	13	6,270	827
2,3,7,8-TCDF	ng/kg	124	87	70%	0.255	72,900	2,900
1,2,3,7,8-PeCDF	ng/kg	124	46	37%	0.164	1,700	95.1
2,3,4,7,8-PeCDF	ng/kg	124	48	39%	0.16	1,050	53.0
1,2,3,4,7,8-HxCDF	ng/kg	124	62	50%	0.0884	2,800	154
1,2,3,6,7,8-HxCDF	ng/kg	124	60	48%	0.0303	671	36.0
1,2,3,7,8,9-HxCDF	ng/kg	124	19	15%	0.0823	35.1	1.72
2,3,4,6,7,8-HxCDF	ng/kg	124	33	27%	0.0538	79.9	4.45
1,2,3,4,6,7,8-HpCDF	ng/kg	124	64	52%	0.0504	804	43.0
1,2,3,4,7,8,9-HpCDF	ng/kg	124	42	34%	0.0816	270	14.3
OCDF	ng/kg	124	73	59%	0.0832	555	50.9
TEQ _{DF}	ng/kg	124	124	100%	0.0593	26,900	1,300

Notes

Mean calculations include detected and nondetected values. Nondetected values were set to one-half the detection limit.

EXHIBIT XV

Table 6-17
Summary Statistics for Dioxin and Furan Concentrations in Surface Soil Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data Mean
					Minimum	Maximum	
2,3,7,8-TCDF	ng/kg	10	9	90%	0.581	161	28.4
1,2,3,7,8-PeCDF	ng/kg	10	8	80%	0.19	5.47	1.17
2,3,4,7,8-PeCDF	ng/kg	10	8	80%	0.264	3.73	1.05
1,2,3,4,7,8-HxCDF	ng/kg	10	10	100%	0.677	6.12	2.82
1,2,3,6,7,8-HxCDF	ng/kg	10	8	80%	0.266	1.82	1.05
1,2,3,7,8,9-HxCDF	ng/kg	10	0	0%	na	na	0.0664
2,3,4,6,7,8-HxCDF	ng/kg	10	10	100%	0.219	2.94	1.28
1,2,3,4,6,7,8-HpCDF	ng/kg	10	10	100%	1.87	61.1	19.6
1,2,3,4,7,8,9-HpCDF	ng/kg	10	9	90%	0.347	4.29	1.56
OCDF	ng/kg	10	10	100%	6.39	347	99.7
TEQ _{DF}	ng/kg	10	10	100%	1.73	66.1	14.7
Area 3							
2,3,7,8-TCDD	ng/kg	11	11	100%	0.575	8,650	1740
1,2,3,7,8-PeCDD	ng/kg	11	9	82%	0.369	57.2	14.6
1,2,3,4,7,8-HxCDD	ng/kg	11	5	45%	0.163	1.53	0.363
1,2,3,6,7,8-HxCDD	ng/kg	11	6	55%	0.829	6.54	1.69
1,2,3,7,8,9-HxCDD	ng/kg	11	10	91%	0.151	3.62	1.18
1,2,3,4,6,7,8-HpCDD	ng/kg	11	11	100%	3	191	57.6
OCDD	ng/kg	11	11	100%	118	3,700	1100
2,3,7,8-TCDF	ng/kg	11	11	100%	2.88	20,600	5480
1,2,3,7,8-PeCDF	ng/kg	11	10	91%	1.6	959	257
2,3,4,7,8-PeCDF	ng/kg	11	10	91%	1.53	465	128
1,2,3,4,7,8-HxCDF	ng/kg	11	11	100%	0.207	2,110	545
1,2,3,6,7,8-HxCDF	ng/kg	11	10	91%	1.68	498	122
1,2,3,7,8,9-HxCDF	ng/kg	11	6	55%	0.359	25.5	6.91
2,3,4,6,7,8-HxCDF	ng/kg	11	9	82%	0.593	69.7	19.8
1,2,3,4,6,7,8-HpCDF	ng/kg	11	10	91%	2.11	668	157

Table 6-17
Summary Statistics for Dioxin and Furan Concentrations in Surface Soil Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
Area 1							
2,3,7,8-TCDD	ng/kg	31	13	42%	0.318	6.58	1.05
1,2,3,7,8-PeCDD	ng/kg	31	10	32%	0.159	1.96	0.294
1,2,3,4,7,8-HxCDD	ng/kg	31	18	58%	0.0802	2.5	0.585
1,2,3,6,7,8-HxCDD	ng/kg	31	24	77%	0.381	16.3	2.97
1,2,3,7,8,9-HxCDD	ng/kg	31	25	81%	0.169	8.03	2.03
1,2,3,4,6,7,8-HpCDD	ng/kg	31	31	100%	0.829	1,010	117
OCDD	ng/kg	31	31	100%	17.1	35,400	3,670
2,3,7,8-TCDF	ng/kg	31	22	71%	0.506	26	5.28
1,2,3,7,8-PeCDF	ng/kg	31	9	29%	0.114	4.91	0.483
2,3,4,7,8-PeCDF	ng/kg	31	14	45%	0.248	7.68	0.828
1,2,3,4,7,8-HxCDF	ng/kg	31	28	90%	0.071	29.2	3.07
1,2,3,6,7,8-HxCDF	ng/kg	31	16	52%	0.155	11.2	1.11
1,2,3,7,8,9-HxCDF	ng/kg	31	3	10%	0.0974	0.868	0.138
2,3,4,6,7,8-HxCDF	ng/kg	31	17	55%	0.119	4.42	0.834
1,2,3,4,6,7,8-HpCDF	ng/kg	31	29	94%	0.0805	103	16.2
1,2,3,4,7,8,9-HpCDF	ng/kg	31	19	61%	0.18	19.8	1.89
OCDF	ng/kg	31	30	97%	0.93	700	94.4
TEQ _{DF}	ng/kg	31	31	100%	0.456	27.2	5.7
Area 2							
2,3,7,8-TCDD	ng/kg	10	7	70%	0.55	46.5	7.63
1,2,3,7,8-PeCDD	ng/kg	10	7	70%	0.153	1.03	0.438
1,2,3,4,7,8-HxCDD	ng/kg	10	7	70%	0.297	1.65	0.754
1,2,3,6,7,8-HxCDD	ng/kg	10	9	90%	0.829	7.88	3.47
1,2,3,7,8,9-HxCDD	ng/kg	10	10	100%	0.701	5.47	2.51
1,2,3,4,6,7,8-HpCDD	ng/kg	10	10	100%	22.4	319	121
OCDD	ng/kg	10	10	100%	518	6,870	2,710

EXHIBIT XV (cont.)

Table 6-17
Summary Statistics for Dioxin and Furan Concentrations in Surface Soil Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
1,2,3,4,7,8,9-HpCDF	ng/kg	11	9	82%	0.685	244	59.8
OCDF	ng/kg	11	10	91%	3.74	363	101
TEQ _{DF}	ng/kg	11	11	100%	1.02	11,200	2420
Area 4							
2,3,7,8-TCDD	ng/kg	13	8	62%	0.544	24.3	3.8
1,2,3,7,8-PeCDD	ng/kg	13	9	69%	0.216	0.992	0.515
1,2,3,4,7,8-HxCDD	ng/kg	13	10	77%	0.186	3.25	0.782
1,2,3,6,7,8-HxCDD	ng/kg	13	12	92%	0.72	6.38	2.62
1,2,3,7,8,9-HxCDD	ng/kg	13	13	100%	0.627	10.9	2.63
1,2,3,4,6,7,8-HpCDD	ng/kg	13	13	100%	19.6	379	99.5
OCDD	ng/kg	13	13	100%	376	50,800	10,100
2,3,7,8-TCDF	ng/kg	13	10	77%	0.237	45.9	9.58
1,2,3,7,8-PeCDF	ng/kg	13	6	46%	0.29	2.82	0.632
2,3,4,7,8-PeCDF	ng/kg	13	9	69%	0.18	1.71	0.603
1,2,3,4,7,8-HxCDF	ng/kg	13	13	100%	0.16	6.73	1.89
1,2,3,6,7,8-HxCDF	ng/kg	13	8	62%	0.229	1.76	0.588
1,2,3,7,8,9-HxCDF	ng/kg	13	4	31%	0.0696	0.181	0.0667
2,3,4,6,7,8-HxCDF	ng/kg	13	6	46%	0.258	1.41	0.446
1,2,3,4,6,7,8-HpCDF	ng/kg	13	13	100%	0.87	22.2	8.38
1,2,3,4,7,8,9-HpCDF	ng/kg	13	8	62%	0.204	2.24	0.63
OCDF	ng/kg	13	13	100%	3	105	36.3
TEQ _{DF}	ng/kg	13	13	100%	1.35	31.1	10.5

Notes

na = not applicable, no detected values

Mean calculations include detected and nondetected values. Nondetected values were set to one-half the detection limit.

EXHIBIT XVI

Table 6-19
Summary Statistics for Dioxin and Furan Concentrations in Subsurface Soils Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
2,3,7,8-TCDF	ng/kg	1	1	100%	1.74	1.74	1.74
1,2,3,7,8-PeCDF	ng/kg	1	0	0%	na	na	0.0434
2,3,4,7,8-PeCDF	ng/kg	1	0	0%	na	na	0.0470
1,2,3,4,7,8-HxCDF	ng/kg	1	0	0%	na	na	0.0565
1,2,3,6,7,8-HxCDF	ng/kg	1	0	0%	na	na	0.0390
1,2,3,7,8,9-HxCDF	ng/kg	1	0	0%	na	na	0.0493
2,3,4,6,7,8-HxCDF	ng/kg	1	0	0%	na	na	0.0382
1,2,3,4,6,7,8-HpCDF	ng/kg	1	0	0%	na	na	0.198
1,2,3,4,7,8,9-HpCDF	ng/kg	1	0	0%	na	na	0.0407
OCDF	ng/kg	1	1	100%	2.83	2.83	2.83
TEQ _{DF}	ng/kg	1	1	100%	1.22	1.22	1.22
Area 3							
2,3,7,8-TCDD	ng/kg	10	10	100%	0.547	11,300	4,100
1,2,3,7,8-PeCDD	ng/kg	10	8	80%	0.781	85.5	35.3
1,2,3,4,7,8-HxCDD	ng/kg	10	4	40%	0.657	1.15	0.464
1,2,3,6,7,8-HxCDD	ng/kg	10	8	80%	0.333	12.9	3.39
1,2,3,7,8,9-HxCDD	ng/kg	10	6	60%	0.321	3.49	1.51
1,2,3,4,6,7,8-HpCDD	ng/kg	10	10	100%	5.41	475	102
OCDD	ng/kg	10	10	100%	202	4,310	1,310
2,3,7,8-TCDF	ng/kg	10	10	100%	1.74	43,000	15,300
1,2,3,7,8-PeCDF	ng/kg	10	9	90%	0.544	1,450	577
2,3,4,7,8-PeCDF	ng/kg	10	8	80%	5	735	314
1,2,3,4,7,8-HxCDF	ng/kg	10	8	80%	12.6	3,060	984
1,2,3,6,7,8-HxCDF	ng/kg	10	9	90%	0.256	691	231
1,2,3,7,8,9-HxCDF	ng/kg	10	7	70%	0.296	43.2	12.5
2,3,4,6,7,8-HxCDF	ng/kg	10	7	70%	2.71	92.7	37.4
1,2,3,4,6,7,8-HpCDF	ng/kg	10	9	90%	0.737	782	274

Table 6-19
Summary Statistics for Dioxin and Furan Concentrations in Subsurface Soils Samples, Dry Weight

		Number of	Number of Detected	Detection	Detected Data		All Data
Analyte	Units	Samples	Measurements	Frequency	Minimum	Maximum	Mean
Area 1							
2,3,7,8-TCDD	ng/kg	39	19	49%	0.268	144	5.18
1,2,3,7,8-PeCDD	ng/kg	39	17	44%	0.139	2.58	0.331
1,2,3,4,7,8-HxCDD	ng/kg	39	21	54%	0.118	3.11	0.529
1,2,3,6,7,8-HxCDD	ng/kg	39	31	79%	0.179	18.2	2.79
1,2,3,7,8,9-HxCDD	ng/kg	39	26	67%	0.291	8.34	1.86
1,2,3,4,6,7,8-HpCDD	ng/kg	39	39	100%	1.33	1,080	114
OCDD	ng/kg	39	39	100%	32.5	30,700	4,500
2,3,7,8-TCDF	ng/kg	39	32	82%	0.306	459	18.6
1,2,3,7,8-PeCDF	ng/kg	39	17	44%	0.154	10.8	0.862
2,3,4,7,8-PeCDF	ng/kg	39	20	51%	0.264	7.44	0.853
1,2,3,4,7,8-HxCDF	ng/kg	39	29	74%	0.188	21.5	2.63
1,2,3,6,7,8-HxCDF	ng/kg	39	26	67%	0.108	8.25	1.01
1,2,3,7,8,9-HxCDF	ng/kg	39	4	10%	0.0711	0.522	0.0981
2,3,4,6,7,8-HxCDF	ng/kg	39	23	59%	0.0707	6.69	0.864
1,2,3,4,6,7,8-HpCDF	ng/kg	39	36	92%	0.118	129	13.4
1,2,3,4,7,8,9-HpCDF	ng/kg	39	21	54%	0.201	12.9	1.33
OCDF	ng/kg	39	35	90%	0.229	777	73.2
TEQ _{DF}	ng/kg	39	39	100%	0.357	195	11.3
Area 2							
2,3,7,8-TCDD	ng/kg	1	1	100%	0.547	0.547	0.547
1,2,3,7,8-PeCDD	ng/kg	1	0	0%	na	na	0.0580
1,2,3,4,7,8-HxCDD	ng/kg	1	0	0%	na	na	0.102
1,2,3,6,7,8-HxCDD	ng/kg	1	1	100%	0.476	0.476	0.476
1,2,3,7,8,9-HxCDD	ng/kg	1	0	0%	na	na	0.170
1,2,3,4,6,7,8-HpCDD	ng/kg	1	1	100%	18.6	18.6	18.6
OCDD	ng/kg	1	1	100%	484	484	484

EXHIBIT XVI (cont.)

Table 6-19
Summary Statistics for Dioxin and Furan Concentrations in Subsurface Soils Samples, Dry Weight

Analyte	Units	Number of Samples	Number of Detected Measurements	Detection Frequency	Detected Data		All Data
					Minimum	Maximum	Mean
1,2,3,4,7,8,9-HpCDF	ng/kg	10	8	80%	1.1	296	101
OCDF	ng/kg	10	10	100%	1.43	412	166
TEQ _{DF}	ng/kg	10	10	100%	1.22	16,200	5,910
Area 4							
2,3,7,8-TCDD	ng/kg	81	56	69%	0.157	1,410	66.8
1,2,3,7,8-PeCDD	ng/kg	81	52	64%	0.0825	12.4	1.25
1,2,3,4,7,8-HxCDD	ng/kg	81	53	65%	0.0594	17.5	1.11
1,2,3,6,7,8-HxCDD	ng/kg	81	67	83%	0.172	53.4	4.72
1,2,3,7,8,9-HxCDD	ng/kg	81	71	88%	0.154	52	3.47
1,2,3,4,6,7,8-HpCDD	ng/kg	81	80	99%	1.92	1,450	146
OCDD	ng/kg	81	81	100%	30.8	59,300	5,370
2,3,7,8-TCDF	ng/kg	81	75	93%	0.375	3,850	170
1,2,3,7,8-PeCDF	ng/kg	81	57	70%	0.119	121	6.27
2,3,4,7,8-PeCDF	ng/kg	81	61	75%	0.095	88	4.50
1,2,3,4,7,8-HxCDF	ng/kg	81	72	89%	0.109	251	13.4
1,2,3,6,7,8-HxCDF	ng/kg	81	54	67%	0.123	64.1	3.83
1,2,3,7,8,9-HxCDF	ng/kg	81	22	27%	0.0567	3.48	0.191
2,3,4,6,7,8-HxCDF	ng/kg	81	43	53%	0.0763	15	1.45
1,2,3,4,6,7,8-HpCDF	ng/kg	81	78	96%	0.115	223	28.9
1,2,3,4,7,8,9-HpCDF	ng/kg	81	57	70%	0.101	31.1	2.77
OCDF	ng/kg	81	75	93%	1.26	11,300	560
TEQ _{DF}	ng/kg	81	81	100%	0.163	1,880	92.9

Notes

na = not applicable, no detected values

Mean calculations include detected and nondetected values. Nondetected values were set to one-half the detection limit.

EXHIBIT XVII

Table 2. Levels of PCDDs and PCDFs in samples of crab hepatopancreas and sediments from the Swedish West Coast.

	Crab	Hepatopancreas		Sediments	
	Idefjorden pg/g	Grebbestad pg/g	Väröfjorden pg/g	Värö Mill pg/g	Mouth of R. Viskan pg/g
2,3,7,8-Tetra-CDF	31	47	590	890	1.6
Total Tetra-CDFs	90	114	800	1600	24
2,3,7,8-Tetra-CDD	17	17	170	120	0.2
Total Tetra-CDDs	17	17	170	230	6.4
1,2,3,7,8-Penta-CDF*	6.0	7.6	45	15	1.3
2,3,4,7,8-Penta-CDF	44	50	130	13	1.7
Total Penta-CDFs	130	150	490	130	30
1,2,3,7,8-Penta-CDD	13	11	28	15	0.9
Total Penta-CDDs	86	76	270	170	13
1,2,3,4,7,8-Hexa-CDF**	12	16	50	1.7	1.9
1,2,3,6,7,8-Hexa-CDF	3	5	10	0.8	1.2
1,2,3,7,8,9-Hexa-CDF	3	3	11	2.0	2.0
2,3,4,6,7,8-Hexa-CDF	16	18	63	1.5	1.6
Total Hexa-CDFs	70	88	280	17	44
1,2,3,4,7,8-Hexa-CDD	8	5	14	3.1	1.6
1,2,3,6,7,8-Hexa-CDD	26	18	71	21	10
1,2,3,7,8,9-Hexa-CDD	3	4	7	8.8	4.3
Total Hexa-CDDs	154	170	465	92	64
Total Hepta-CDFs	23	28	90	16	300
Total Hepta-CDDs	32	30	85	31	190
Octa-CDF	< 1	< 1	< 2	19	330
Octa-CDD	< 1	< 1	< 2	87	900

* Not separated from 1,2,3,4,8-Penta-CDF

** Not separated from 1,2,3,4,7,9-Hexa-CDF

EXHIBIT XVIII

Table 3: Distribution of 2378-TCDD/F Concentrations in Sludge

	No. Samples	No.ND() Samples	Mean (ng/kg)	Median (ng/kg)	90 % (ng/kg)	Maximum (ng/kg)
Kraft Mills						
2378-TCDD	70	2	95	48	180	1,390
2378-TCDF	69	0	806	161	1570	17,100
Sulfite Mills						
2378-TCDD	13	0	16	4.8	47	58
2378-TCDF	10	0	130	65	250	584

EXHIBIT XIX

Table 5. San Jacinto River Waste Pits Sediment PCDD/PCDF Results

PCDD/PCDF Congener	SE-04 7/12/05 (pg/g)	SE-05 7/12/05 (pg/g)	SE-07 7/12/05 (pg/g)	SE-08 7/12/05 (pg/g)	SE-09 7/13/05 (pg/g)	SE-10 7/13/05 (pg/g)	SE-11 7/13/05 (pg/g)	SE-15 8/18/05 (pg/g)	SE-15dup 8/18/05 (pg/g)	Average (pg/g)
2,3,7,8-TCDD	908	814	51.2	18,500 J	5,710	12,900 J	17,900 J	21,000	23,000	8,111.89
1,2,3,7,8-PeCDD	12.4	9.74	1.16 LJ	182	363	349	323	240	290	177.19
1,2,3,4,7,8-HxCDD	1.215 ND	1.195 ND	1.24 ND	3.55	4.83	4.71	4.2	3.5	1.75 ND	2.99
1,2,3,6,7,8-HxCDD	3	1.49 LJ	3.21	11	27.9	26.9	15.9	8.2	8.1	12.77
1,2,3,7,8,9-HxCDD	3.94	1.5 LJ	4.87	5.74	10.2	10.1	7.03	2.25 ND	2.25 ND	6.20
1,2,3,4,6,7,8-HpCDD	128	43.8	147	188	658	591	367	95	90	303.26
OCDD	-	-	-	-	-	-	-	1,200	1,200	1,200
2,3,7,8-TCDF	4,210	3,530	246	41,300 J	8,430 J	20,600 J	36,700 J	82,000	93,000	16,430.86
1,2,3,7,8-PeCDF	107	71.7	3.7	1,900	2,400	3,770	2,710	2,800	2,900	1,566.06
2,3,4,7,8-PeCDF	89	61.8	3.6	1,290	1,480	2,330	2,030	2,200	2,300	1,040.63
1,2,3,4,7,8-HxCDF	129	99.1	4.84	5,560	5,220	8,660	4,940	3,900	4,600	3,516.13
1,2,3,6,7,8-HxCDF	31.3	26.3	1.24 ND	1,390	1,360	2,290	1,270	1,100	1,200	909.83
2,3,4,6,7,8-HxCDF	7.15	5.09	1.24 ND	222	229	349	216	210	210	147.07
1,2,3,7,8,9-HxCDF	13	8.57	1.24 ND	440	451	656	403	410	390	281.83
1,2,3,4,6,7,8-HpCDF	39.8	26.2	1.24 ND	962	1,300	2,360	1,290	1,100	1,300	854.18
1,2,3,4,7,8,9-HpCDF	11.3	8.36	0.398 LJ	3.54	531	878	477	440	520	272.80
OCDF	-	-	-	-	-	-	-	390	450	420
TCDD TEQ (pg/g)	1,391.96	1,212.5	81.43	24,030.8	8,187.18	17,359.06	23,290.25	30,764	34,028	10,793.31

Abbreviations: CRQL = contract required quantitation limit; EDL = estimated detection limit; IDL = instrument detection limit; J = result is estimated; L = reported concentration is between the IDL and the CRQL; ND = not detected at the laboratory reported IDL. (Values for ND results represent sample EDL \pm 2); pg/g = picograms per gram; TCDD = tetrachlorodibenzo-p-dioxin; PeCDD = pentachlorodibenzo-p-dioxin; HxCDD = hexachlorodibenzo-p-dioxin; HpCDD = heptachlorodibenzo-p-dioxin; OCDD = octachlorodibenzo-p-dioxin; TCDF = tetrachlorodibenzofuran; PeCDF = pentachlorodibenzofuran; HxCDF = hexachlorodibenzofuran; HpCDF = heptachlorodibenzofuran; OCDF = octachlorodibenzofuran

EXHIBIT XX

Table 9. Average TCDD TEQ Concentrations (pg/g), On-Site & Off-Site Locations

Sediment Sample Collection Location	Count	Average (pg/g)	Minimum (pg/g)	Maximum (pg/g)	Standard Deviation
SJRWP, On-Site Samples	9	15,594	80.92	34,028	13,264
Down-Stream from SJRWP, SJR, HSC, & UGB	59	13.75	0.739	86.16	15.5
SJRWP Site-Vicinity, SJR Near SJRWP	31	82.24	1.997	572.5	131
Houston Ship Channel, Above/West of SJR	62	65.69	4.904	856.8	134
Up-Stream & Tributaries to SJR, HSC, or UGB	56	15.97	0.759	102.9	20.4
All Off-Site Samples	208	40.04	0.739	856.8	93.7

Abbreviations: pg/g = picograms per gram; SJRWP = San Jacinto River Waste Pits; SJR = San Jacinto River; HSC = Houston Ship Channel; UGB = Upper Galveston Bay, TCDD TEQ = tetrachlorodibenzo-p-dioxin toxic equivalent.

EXHIBIT XXI

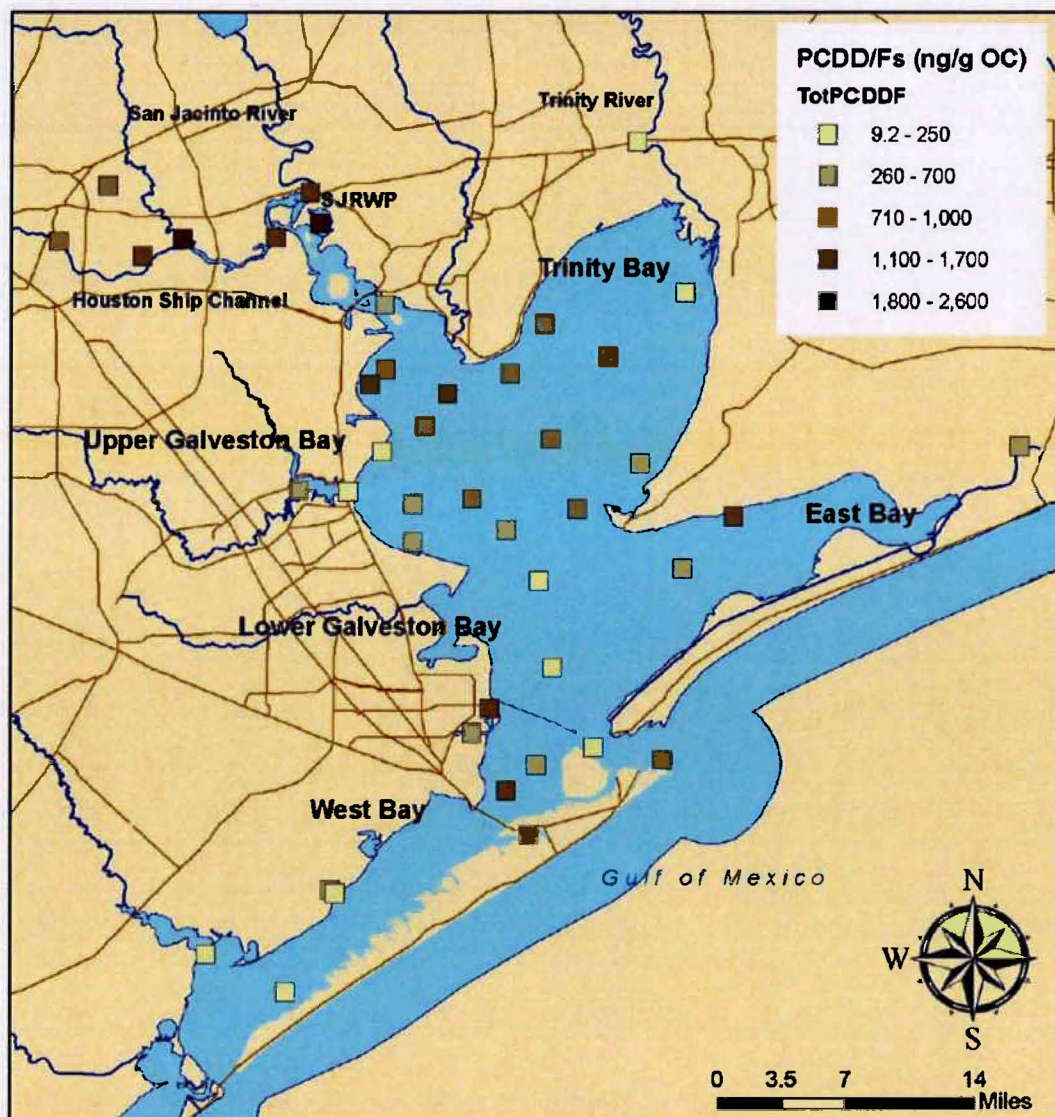


EXHIBIT XXII

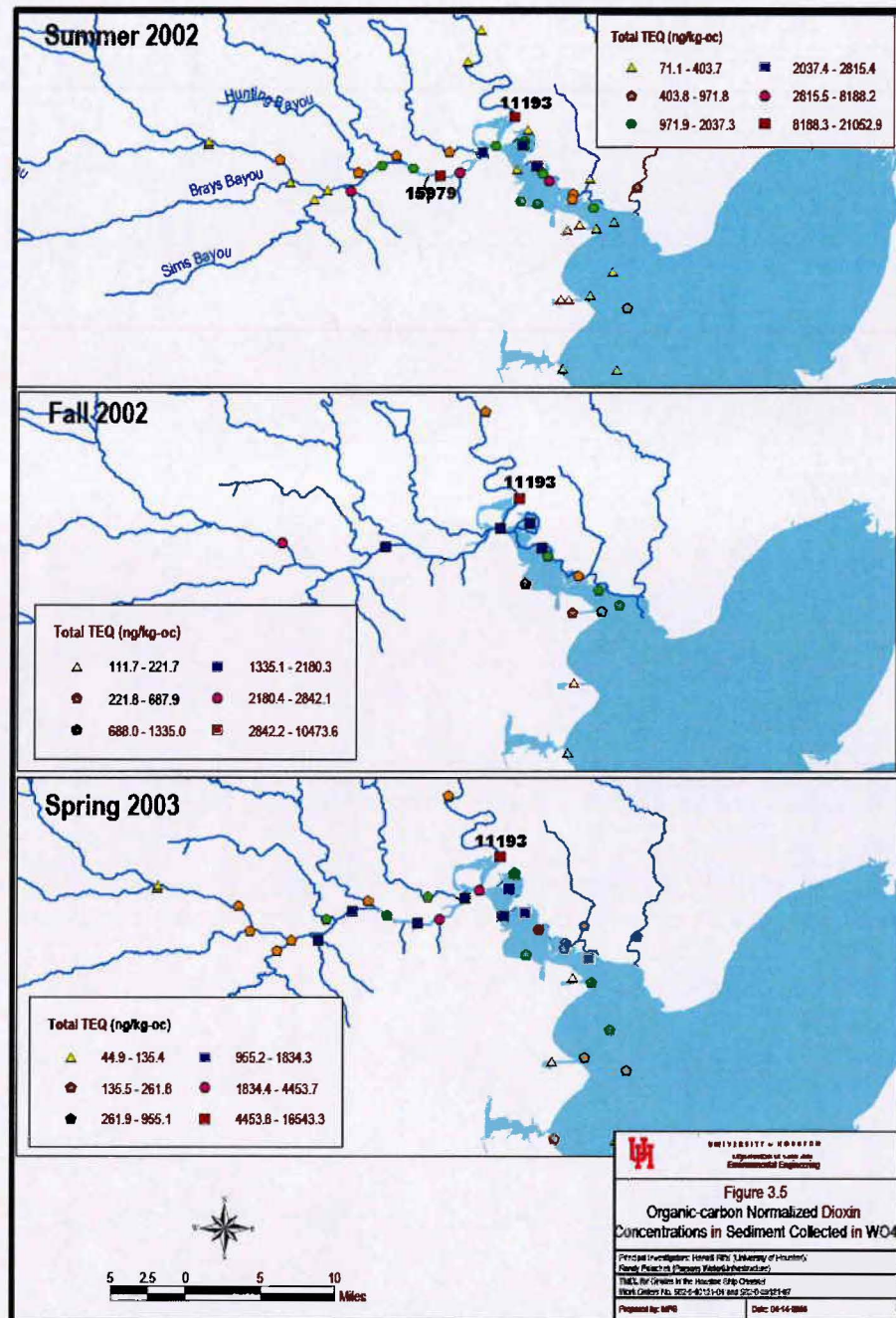


EXHIBIT XXII (CONT.)

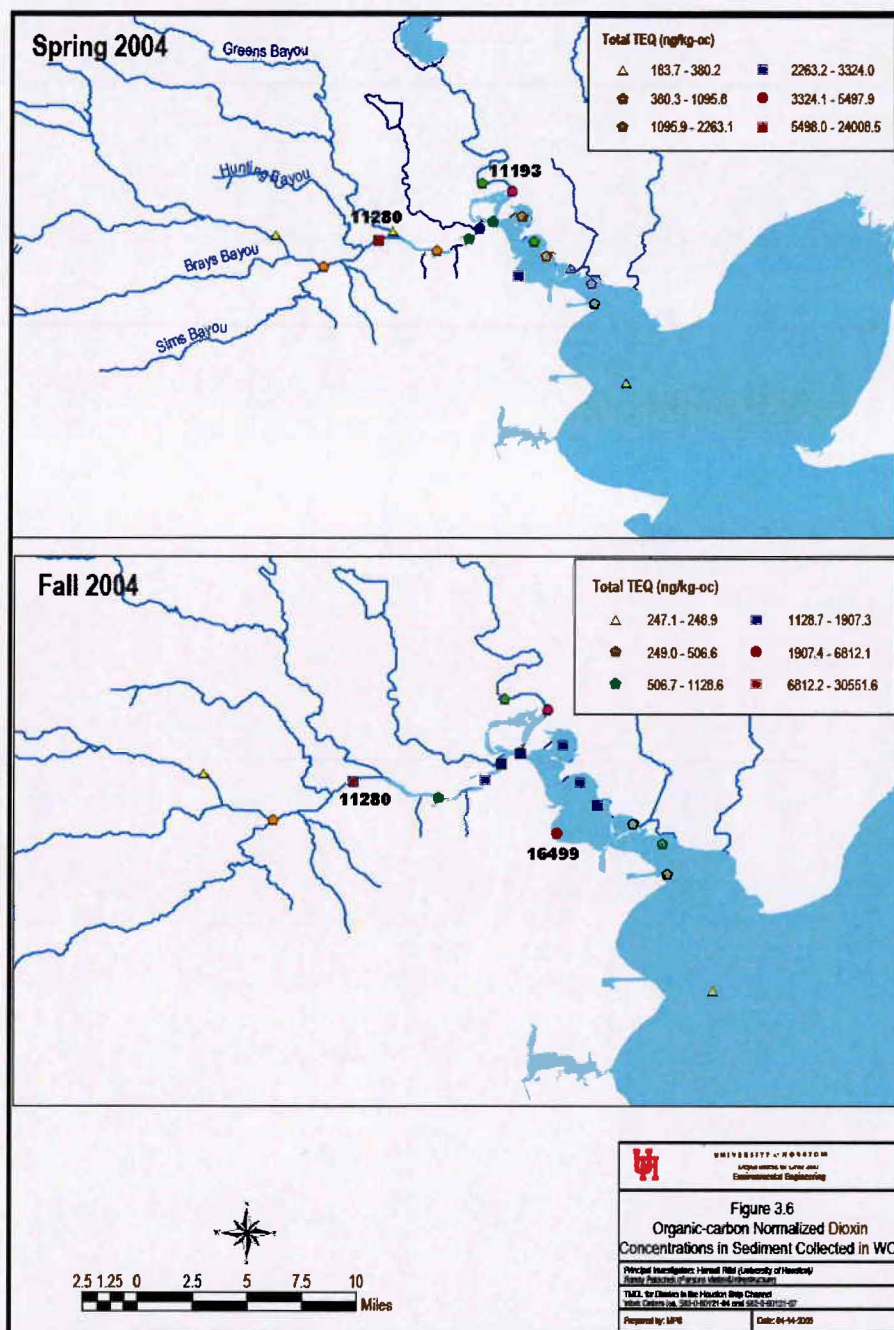


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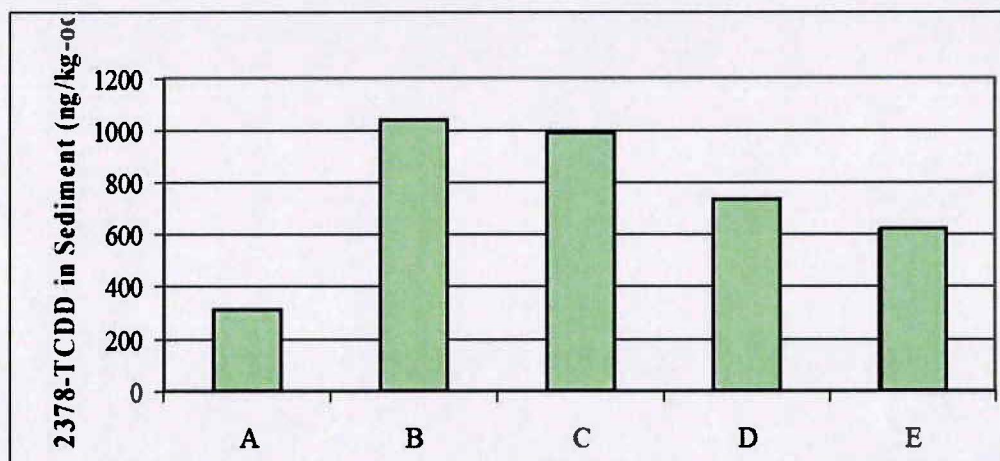
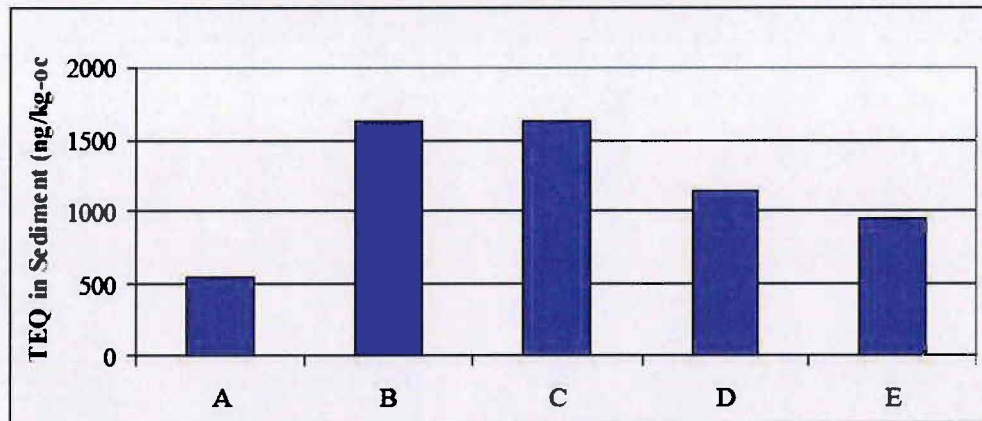


Figure 3.10 Dioxin Concentrations along Transect at Station 15979

EXHIBIT XXIV

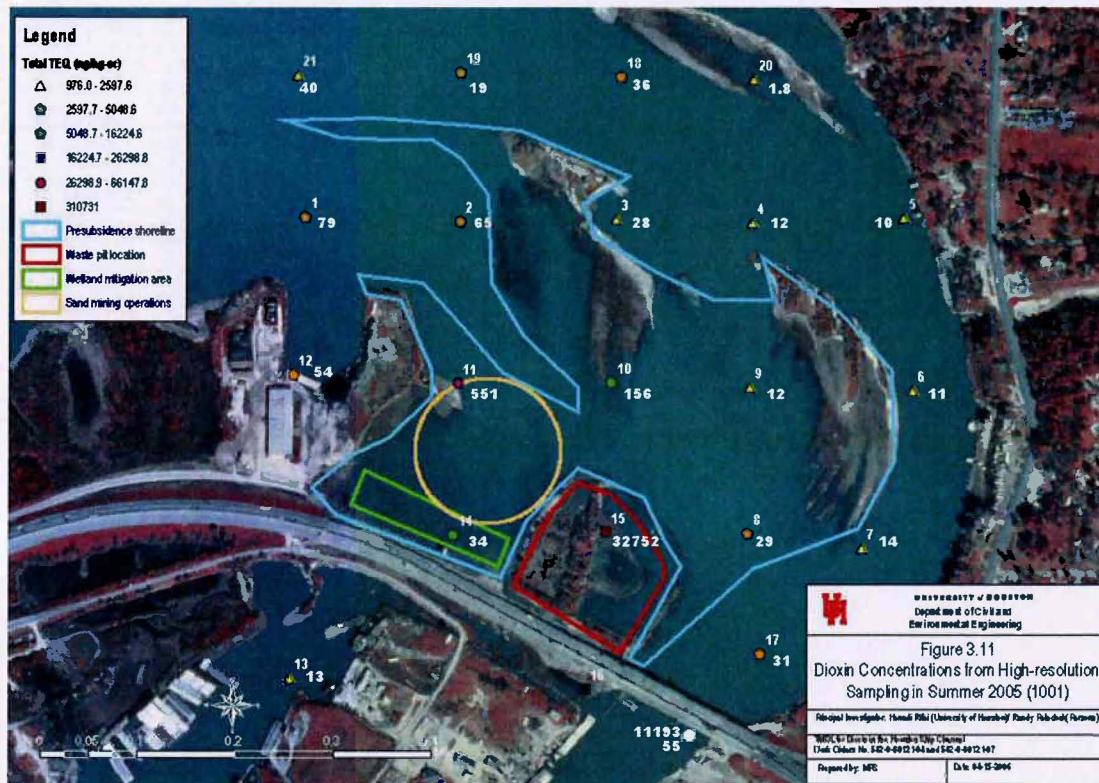


EXHIBIT XXV

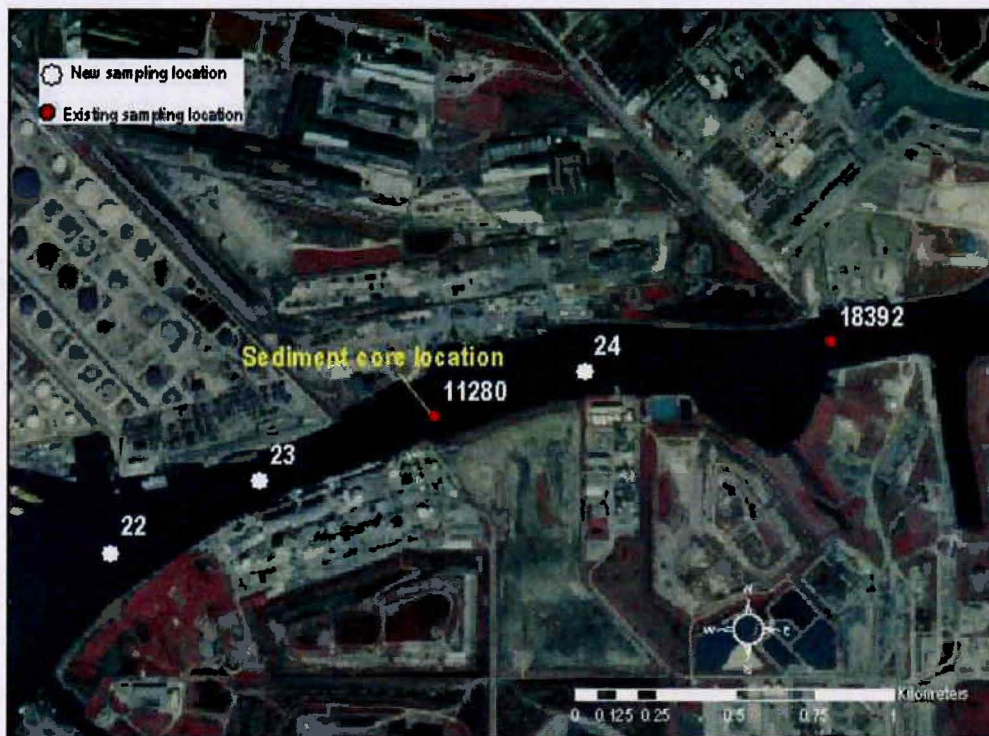


Figure 3.4a Sampled Locations in Segment 1007 in Summer 2005

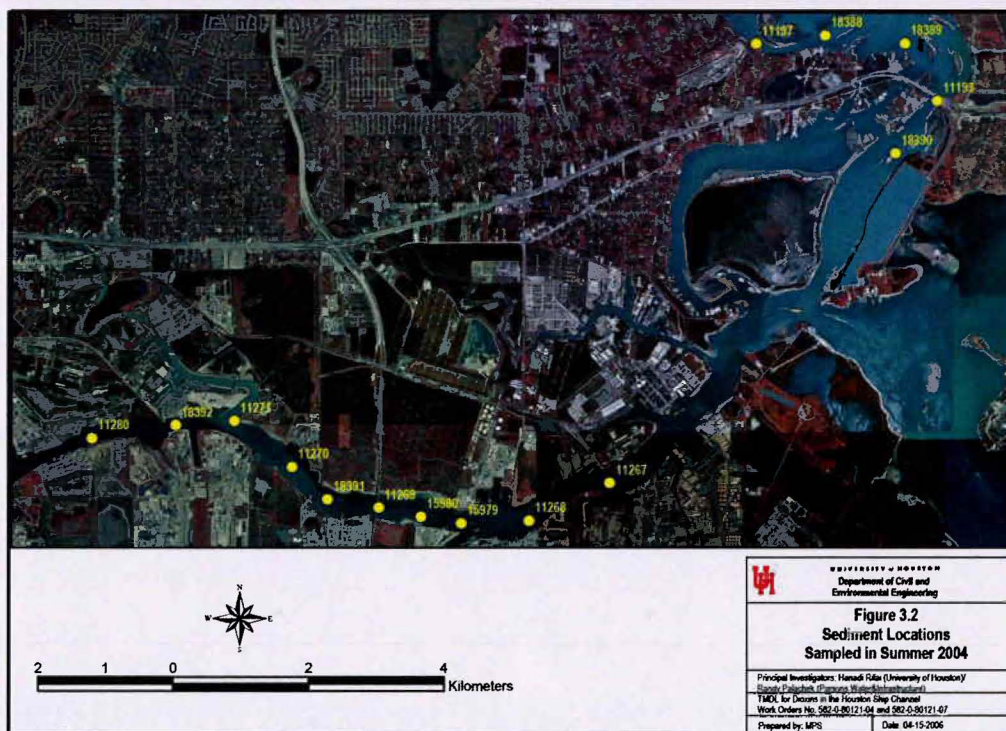


EXHIBIT XXVI

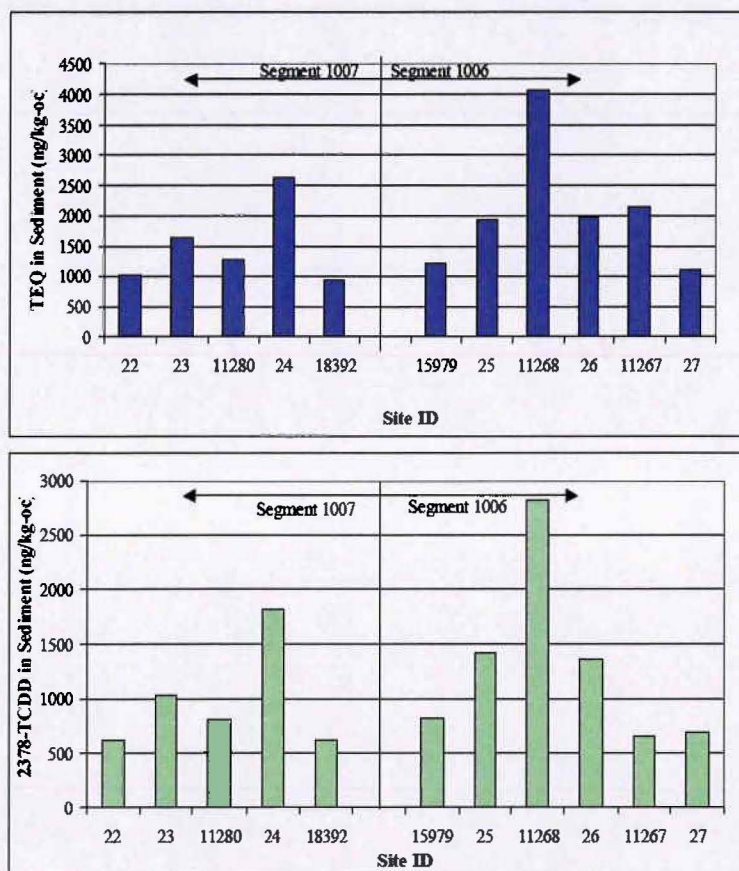


Figure 3.12 Organic-carbon Normalized Concentrations from Summer 2005 High-Resolution Sediment Sampling

EXHIBIT
XXVII

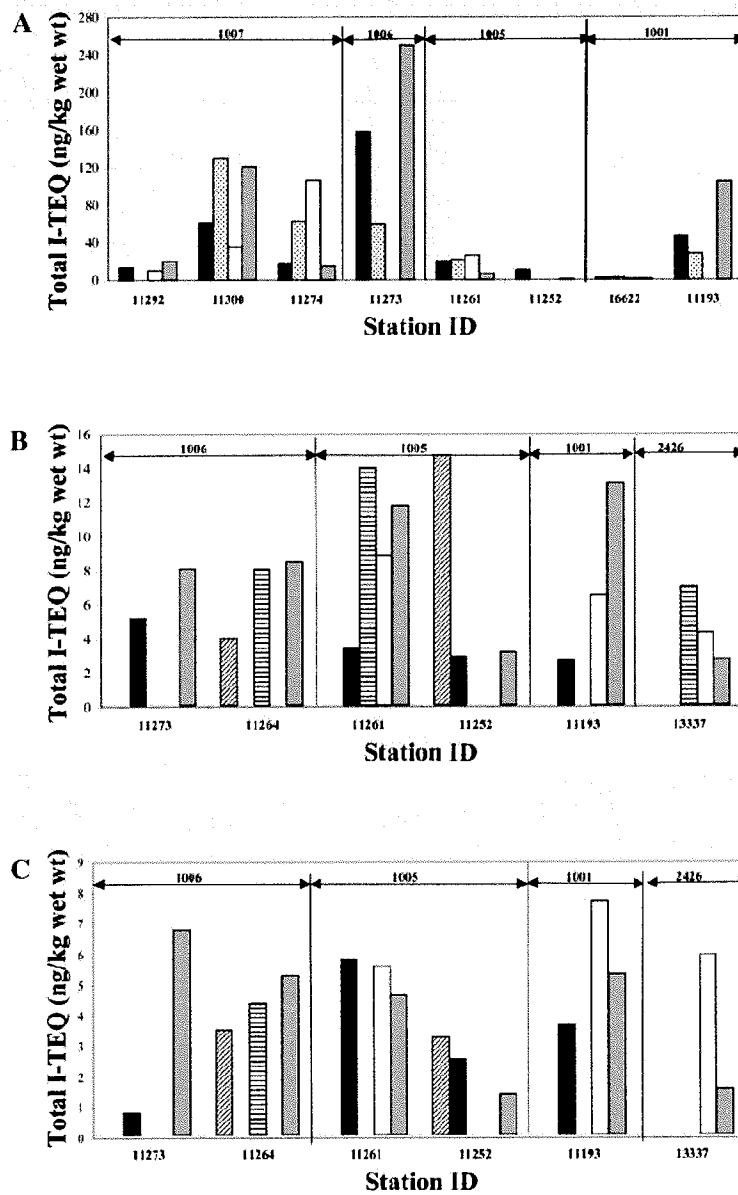


Figure 4. Comparison of past and current I-TEQ levels in (a) sediment, (b) catfish, and (c) crab by year [1990 (▨), 1993 (■), 1994 (▩), 1996 (▧), 2001 (□), and 2002 (▦)].

EXHIBIT XXVIII

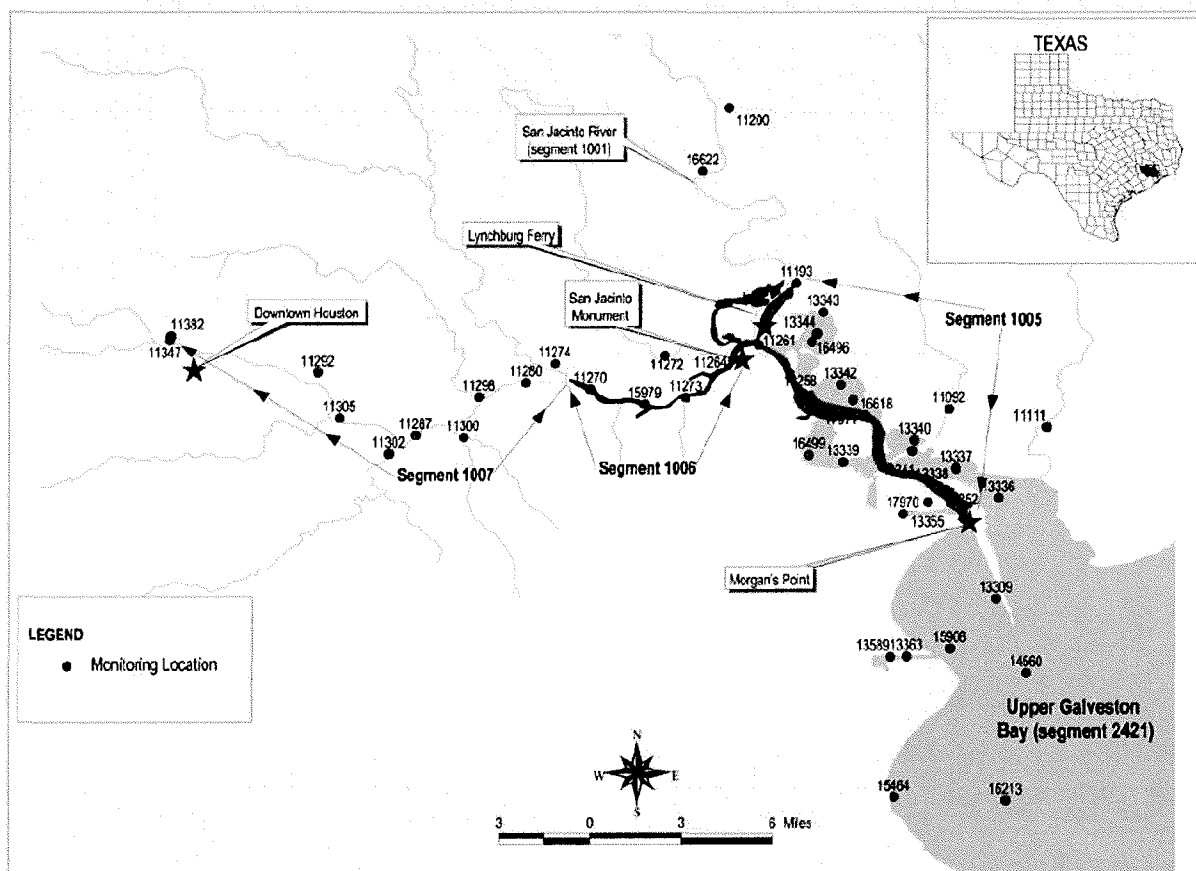


EXHIBIT XXIX

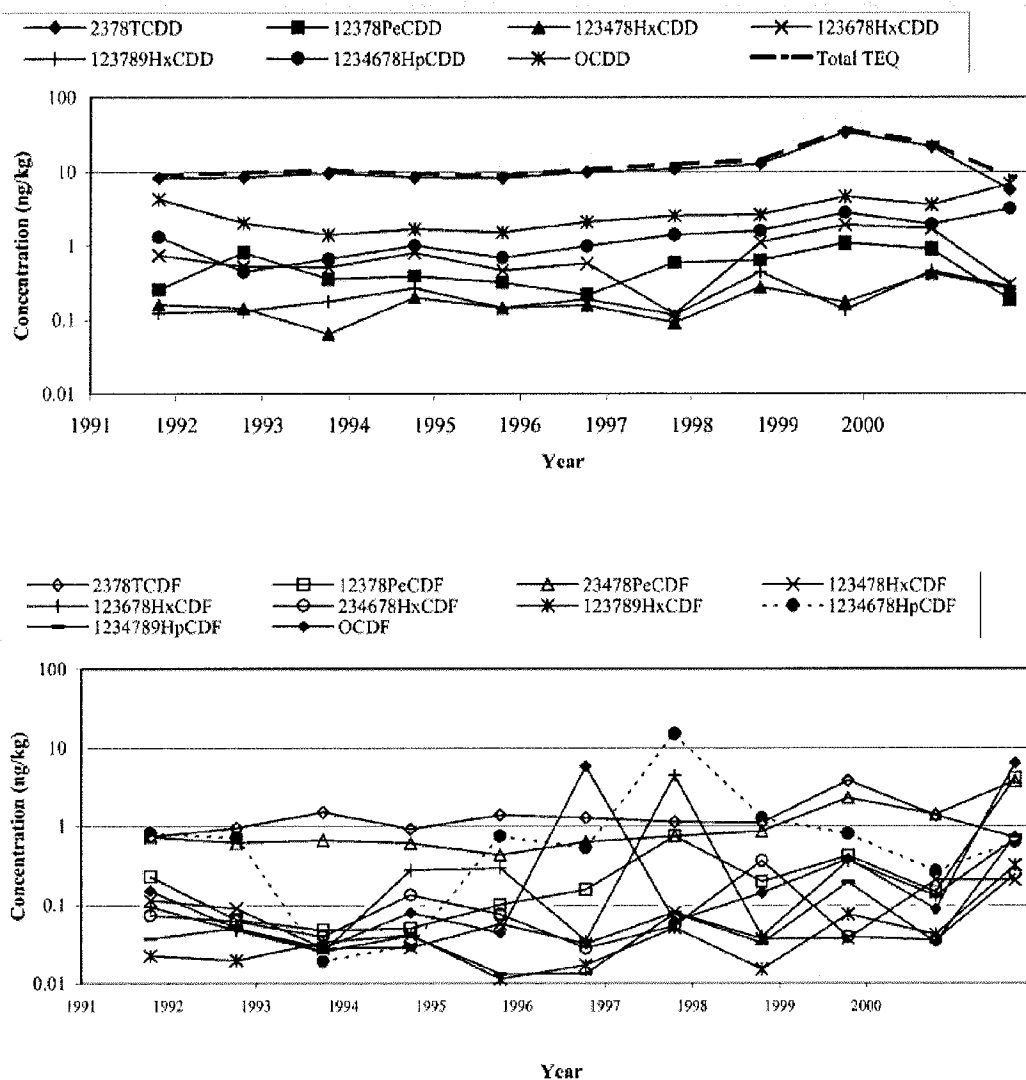


Figure 5. Time series of dioxin concentrations in catfish at San Jacinto monument.

Study Sample Sites for the Houston Ship Channel, Lower San Jacinto River, and Upper Galveston Bay.

The map displays the following study sample sites:

- Site 1: HAC Towing Barge** (located in the upper left area of the map)
- Site 2: Houston Ferry** (located in the central area of the map)
- Site 3: Houston Tug Boat** (located in the lower right area of the map)
- Site 4: Houston Tug Boat** (located in the lower right area of the map)

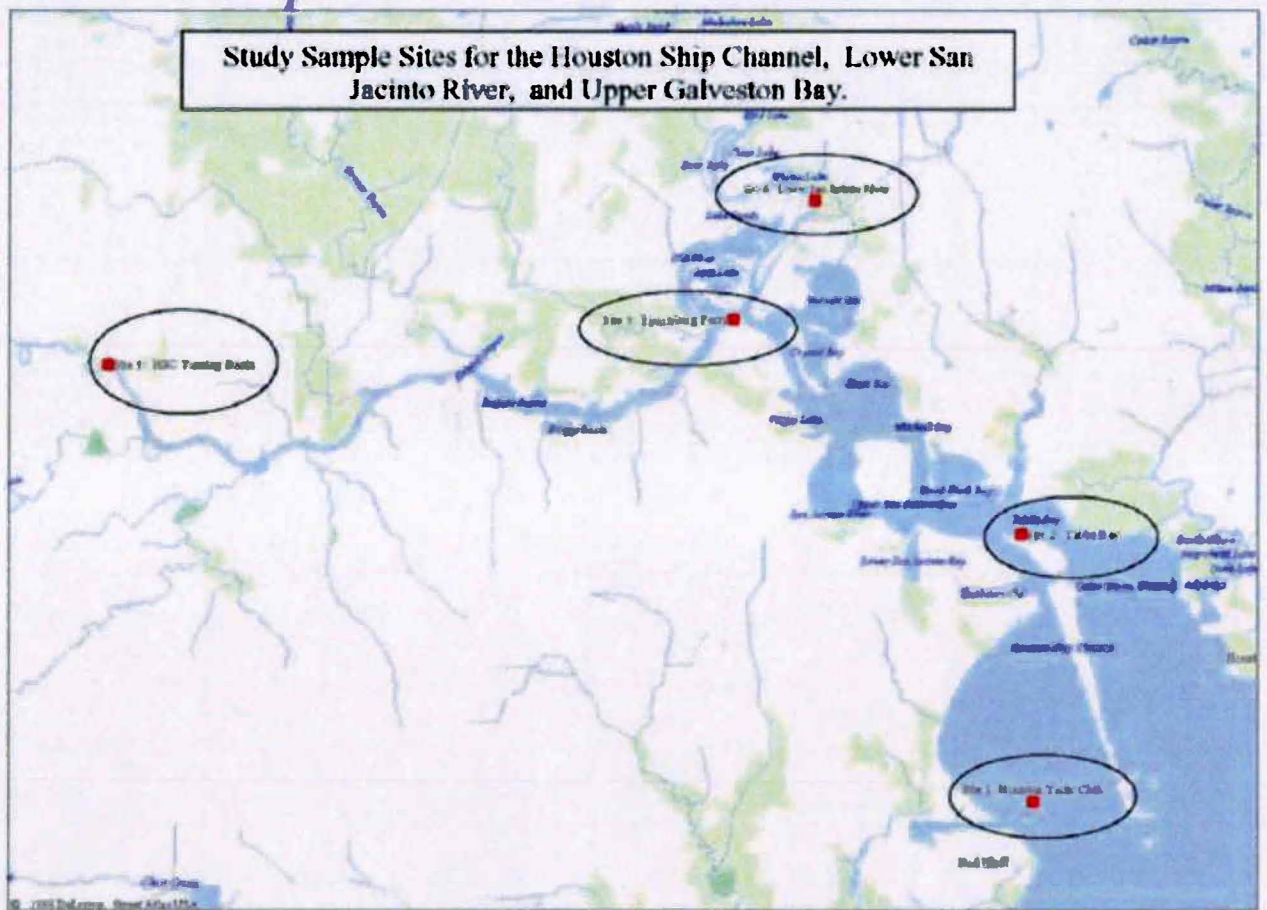


EXHIBIT XXXI

Table 4a. Dioxin/Furan Toxic Equivalent Concentration (TEC) (pg/g) Detected in Fish and Blue Crabs from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.				
Species	# Detected/ # Sampled	Mean TEC ± S.D. (Min-Max) ¹	Health Assessment Comparison Value ² (pg/g)	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Blue crab	2/2	1.165± 0.837 (0.574, 1.757)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg –day EPA slope factor: 1.56 X 10 ⁻⁴ per pg/kg –day
Spotted seatrout	1/2	0.958± 1.098 (nd, 1.734)		
Black drum	2/2	0.168± 0.093 (0.102, 0.234)		
Red drum	1/2	0.123± 0.036 (nd, 0.148)		
Southern flounder	0/1	nd		
All fish species	4/7	0.384± 0.597 (0.098-1.734)		
All species	6/9	0.558± 0.698 (0.098-1.757)		
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Blue crab	2/2	2.419± 0.245 (2.245, 2.592)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg –day EPA slope factor: 1.56 X 10 ⁻⁴ per pg/kg –day
Blue catfish	2/2	0.229± 0.028 (0.209, 0.248)		
Spotted seatrout	2/2	0.201± 0.001 (0.200, 0.201)		
Hybrid striped bass	1/1	1.525		
Black drum	1/2	0.184± 0.131 (nd, 0.277)		
All fish species	6/7	0.393± 0.502 (0.092-1.525)		
All species	8/9	0.843± 0.997 (0.092-2.592)		
HSC-Lynchburg ferry (Site 3)				
Blue crab	2/2	2.247± 0.232 (2.083, 2.411)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg –day EPA slope factor: 1.56 X 10 ⁻⁴ per pg/kg –day
Blue catfish	3/3	2.764± 2.673 (0.967-5.837)		
Smallmouth buffalo	1/1	3.474		
White bass	1/1	1.254		
Black drum	1/1	0.132		
Channel catfish	0/1	nd		
All fish species	6/7	1.916± 2.051 (0.132-5.837)		
All species	8/9	1.990± 1.784 (0.132-5.837)		

¹ Minimum concentration to maximum concentration; (range = maximum conc - minimum conc)

² derived from the MRL or RfD for noncarcinogens or the EPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of 1x10⁻⁴

³ nd-not detected at concentrations above the laboratory's reporting limit

EXHIBIT XXXII

Table 4b. Dioxin/Furan Toxic Equivalent Concentration (TEC) (pg/g) Detected in Fish and Blue Crabs from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.				
Species	# Detected/ # Sampled	Mean TEC ± S.D. (Min-Max) ¹	Health Assessment Comparison Value ²	Basis for Comparison Value
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Blue crab	2/2	3.107± 0.013 (3.098, 3.116)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg-day EPA slope factor: 1.56 X 10 ⁻⁴ per pg/kg-day
Blue catfish	2/2	6.040± 4.164 (3.096, 8.985)		
Spotted seatrout	1/2	0.233± 0.161 (nd, 347)		
Hybrid striped bass	1/1	1.541		
Red drum	1/2	0.097± 0.006 (nd, 0.102)		
All fish species	5/7	2.040± 3.258 (0.093-8.985)		
All species	7/9	2.277± 2.860 (0.093-8.985)		
HSC- Turning Basin (Site 5)				
Blue crab	2/2	1.216± 0.209 (1.068, 1.363)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg-day EPA slope factor: 1.56 X 10 ⁻⁴ per pg/kg-day
Blue catfish	3/3	5.491± 2.113 (3.370- 7.596)		
Common Carp	2/2	1.461± 0.574 (1.056, 1.867)		
Smallmouth buffalo	2/2	1.673± 0.840 (1.079, 2.267)		
All fish species	7/7	3.249± 2.464 (1.056-7.596)		
All species	9/9	2.797± 2.315 (1.056-7.596)		
All Sites Combined				
Blue crab	10/10	2.031± 0.843 (0.574- 3.116)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg-day EPA slope factor: 1.56 X 10 ⁻⁴ per pg/kg-day
Blue catfish	10/10	3.730± 3.125 (0.209- 8.985)		
Common carp	2/2	1.461± 0.574 (1.056, 1.867)		
Hybrid striped bass	2/2	1.532± 0.011 (1.525, 1.541)		
Smallmouth buffalo	3/3	2.273± 1.198 (1.079- 3.474)		
White bass	1/1	1.254		
Spotted seatrout	4/6	0.464± 0.627 (nd - 1.734)		
Black drum	4/5	0.167± 0.083 (nd - 0.277)		
Red drum	2/4	0.110± 0.026 (nd - 0.148)		
All fish species	28/35	1.597± 2.240 (nd - 8.985)		
All species	38/45	1.693± 2.014 (nd - 8.985)		

¹ Minimum concentration to maximum concentration; (range = maximum conc - minimum conc)² derived from the MRL or RfD for noncarcinogens or the EPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of 1x10⁻⁴³ nd-not detected at concentrations above the laboratory's reporting limit

EXHIBIT XXXIII

Table 5a. PCDFs/PCDDs toxicity equivalent (TEQ) concentrations (pg/g) in fish and/or blue crab collected in 2006 from Trinity Bay and Upper Galveston Bay (presented by species and site).				
Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
Site 1 Pine Gully				
Black drum	1/1	0.0011	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Blue crab	2/2	0.0013± 0.0006 (0.0008-0.0017)		
Gaftsailsail catfish	3/3	1.9359± 1.5970 (0.9405-3.7779) ¹		
Red drum	1/1	0.2002		
Spotted seatrout	2/2	2.3355± 0.4879 (1.9905-2.6805)	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
All Fish, Site 1	7/7	1.5257± 1.3685 (0.0011-3.7779)		
All Species, Site 1	9/9	1.1869± 1.3625 (0.0008-3.7779)		
Site 2 Clifton Beach				
Black drum	1/1	0.0004	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Blue crab	1/2	0.0144± 0.0204 (ND-0.0288)		
Gaftsailsail catfish	3/3	1.642± 0.7551 (0.9395-2.4406)		
Southern flounder	1/1	0.0006		
Spotted seatrout	2/2	1.2850± 0.1329 (1.1910-1.3790)	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
All Fish, Site 2	7/7	1.0711± 0.8680 (0.0004-2.4406)		
All Species, Site 2	8/9	0.8363± 0.8844 (ND-2.4406)		
Site 3 Lone Oak Bayou				
Black drum	1/1	0.0003	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Blue crab	2/2	0.0008± 0.0007 (0.0003-0.0013)		
Gaftsailsail catfish	1/1	1.4237		
Red drum	3/3	0.0340± 0.0580 (0.0003-0.1009)		
Southern flounder	1/1	0.1000	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
Spotted seatrout	1/1	0.2804		
All Fish, Site 3	7/7	0.2723± 0.5175 (0.0003-1.4237)		
All Species, Site 3	9/9	0.2120± 0.4639 (0.0003-1.4237)		

EXHIBIT XXXIII (cont.)

Table 5b. PCDF/PCDD toxicity equivalent (TEQ) concentrations (pg/g) in fish and/or blue crab collected in 2006 from Trinity Bay and Upper Galveston Bay (presented by site and species).				
Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
Site 4 Trinity River				
Black drum	1/1	1.0500	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Gaftsailsail catfish	2/2	2.0557± 1.209 (1.2009-2.9105)		
Red drum	1/1	0.0003		
Southern flounder	1/1	0.0400	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
Spotted seatrout	2/2	1.3855± 1.6659 (0.2075-2.5634)		
All Fish, Site 4	7/7	1.1389± 1.1938 (0.0003-2.9105)		
Site 5 HL&P Outfall				
Black drum	1/1	0.1000	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Blue crab	3/4	0.0527± 0.0619 (ND-0.1202)		
Gaftsailsail catfish	3/3	6.1577± 8.0638 (1.3555-15.4675)		
Southern flounder	1/1	0.0204	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
Spotted seatrout	3/3	0.7568± 0.6442 (0.3700-1.5004)		
All Fish, Site 5	8/8	2.6080± 5.2365 (0.0204-15.4675)		
All Species, Site 5	11/12	1.7562± 4.3628 (ND-15.4675)		
Site 6 Umbrella Point				
Black drum	1/1	0.0012	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Blue crab	2/2	0.0881± 0.1125 (0.0086-0.1677)		
Gaftsailsail catfish	2/2	0.2153± 0.2993 (0.0036-0.4270)		
Red drum	1/1	0.0002	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
Southern flounder	1/1	0.0002		
Spotted seatrout	2/2	0.0518± 0.0305 (0.0302-0.0734)		
All Fish, Site 6	7/7	0.0765± 0.1569 (0.0002-0.4270)		
All Species, Site 6	9/9	0.0791± 0.1416 (0.0002-0.4270)		

EXHIBIT XXXIII (cont.)

Table 5c. PCDF/PCDD toxicity equivalent (TEQ) concentrations (pg/g) in fish and/or blue crab collected in 2006 from Trinity Bay and Upper Galveston Bay (presented by site).				
Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
All Sites				
Black drum	6/6	0.1922 ± 0.4221 (0.0003-1.0500)	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^5 per mg/kg/day
Blue crab	10/12	0.0350 ± 0.0580 (ND-0.1677)		
Gulfopsail catfish	14/14	2.5124 ¹ ± 3.8544 (0.0036-15.4675)		
Red drum	6/6	0.0504 ± 0.0837 (0.0002-0.2002)		
Southern flounder	5/5	0.0322 ± 0.0413 (0.0002-0.1000)		
Spotted seatrout	12/12	1.0555 ± 0.9698 (0.0302-2.6805)		
All Fish	43/43	1.1501 ± 2.4373 (0.0002-15.4675)		
All Species	53/55	0.9068 ± 2.1993 (ND-15.4675)		

EXHIBIT XXXIV

Figure 1. Trinity Bay and Upper Galveston Bay Sample Site Map

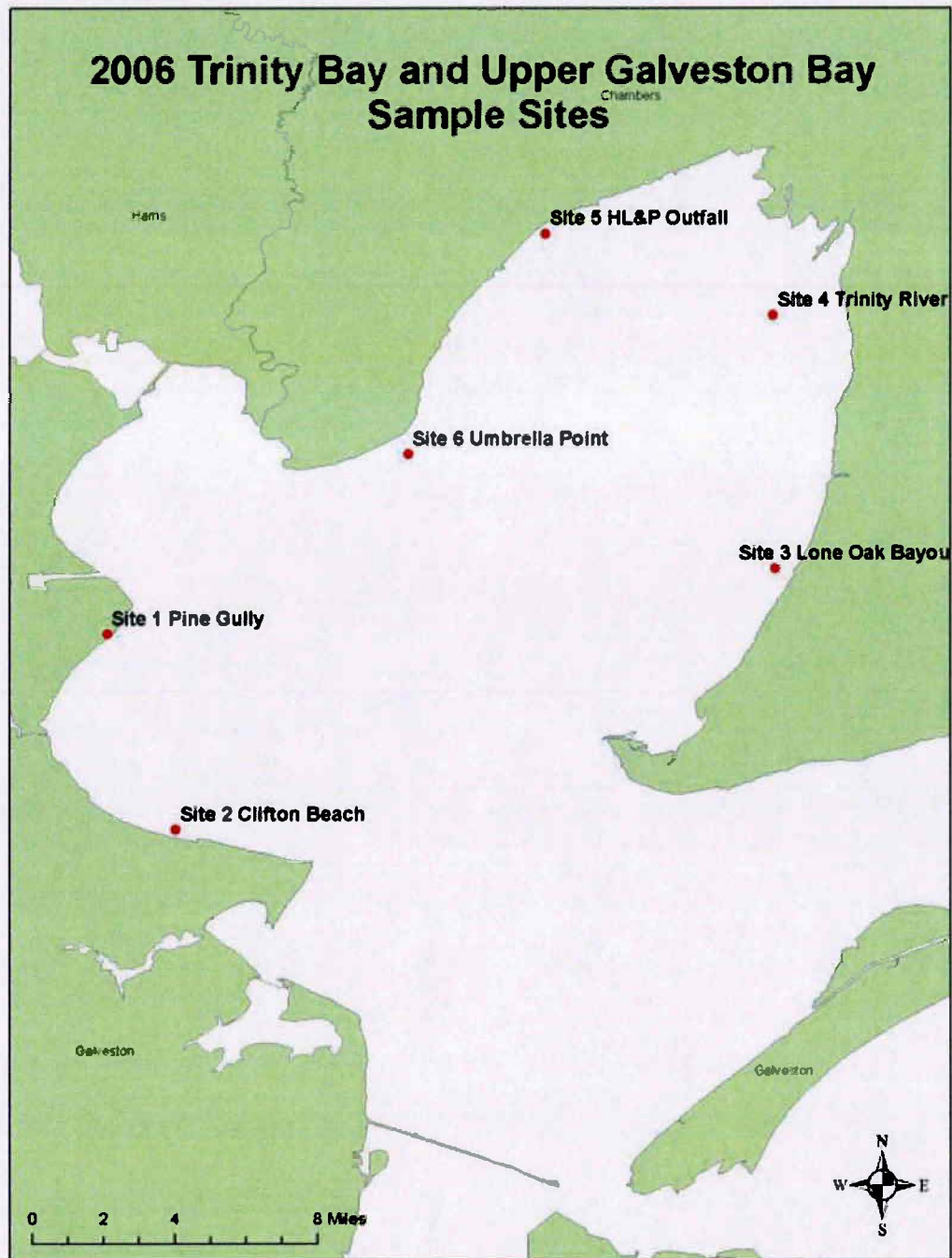


EXHIBIT XXXV

Table 5a. PCDFs/PCDDs toxicity equivalents (TEQs – shown in pg/g) in fish and/or blue crab collected in 2006 and 2007 from Lower Galveston Bay (presented by species and site).

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
Site 1 Hanna Reef				
Black drum	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Red drum	1/1	0.0119		
All Fish, Site 1	1/2	0.0060± 0.0084 (ND-0.0119)	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
Site 2 Bolivar Spoil Island				
Blue crab	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Gaftopsail catfish	1/1	1.6740		
Spotted seatrout	1/1	0.0201	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
All Fish, Site 2	2/2	0.8471± 1.1694 (0.0201-1.6740)		
All Species, Site 2	2/3	0.5647± 0.9607 (ND-1.6740)		
Site 3 Campbell Bayou				
Gaftopsail catfish	1/1	0.1652	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Spotted seatrout	1/1	0.0897		
All Fish, Site 3	2/2	0.1275±0.0534 (0.0897-0.1652)	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
Site 4 Snake Island				
Blue crab	1/1	0.1321	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Gaftopsail catfish	1/1	0.2711		
All Species, Site 2	2/2	0.2016±0.0983 (0.1321-0.2711)	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
Site 5 Dollar Point				
Red drum	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Southern flounder	1/1	0.0011		
Spotted seatrout	1/1	1.4858	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
All Fish, Site 5	2/3	0.4956 ± 0.8575 (ND-1.4858)		
Site 6 Redfish Island				
Black drum	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0 x 10 ⁻⁹ mg/kg/day
Gaftopsail catfish	1/1	3.4839		
Spotted seatrout	1/1	3.3090	3.49	EPA slope factor: 1.56 x 10 ⁵ per mg/kg/day
All Fish, Site 6	2/3	2.2643 ± 1.9629 (ND-3.4839)		

EXHIBIT XXXV (cont.)

Table 5b. PCDF/PCDD toxicity equivalents (TEQs – shown in pg/g) in fish and/or blue crab collected in 2006 and 2007 from Lower Galveston Bay (presented by site and species).				
Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
Site 7 Galveston Jetties				
Spotted seatrout	1/1	0.0007	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^5 per mg/kg/day
All Sites				
Black drum	0/2	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^5 per mg/kg/day
Blue crab	1/2	0.06605 ± 0.0934 (ND-0.1321)		
Gaftsail catfish	4/4	1.3986 ± 1.5510 (0.1652-3.4839)		
Red drum	1/2	0.005950 ± 0.0084 (ND-0.0119)		
Southern flounder	1/1	0.0011		
Spotted seatrout	5/5	0.9811 ± 1.4451 (0.0007-3.3090)		
All Fish	11/14	0.7509 ± 1.2500 (ND-3.4839)		
All Species	12/16	0.6653 ± 1.1872 (ND-3.4839)		

EXHIBIT XXXVI

Figure 1. Lower Galveston Bay Sample Site Map

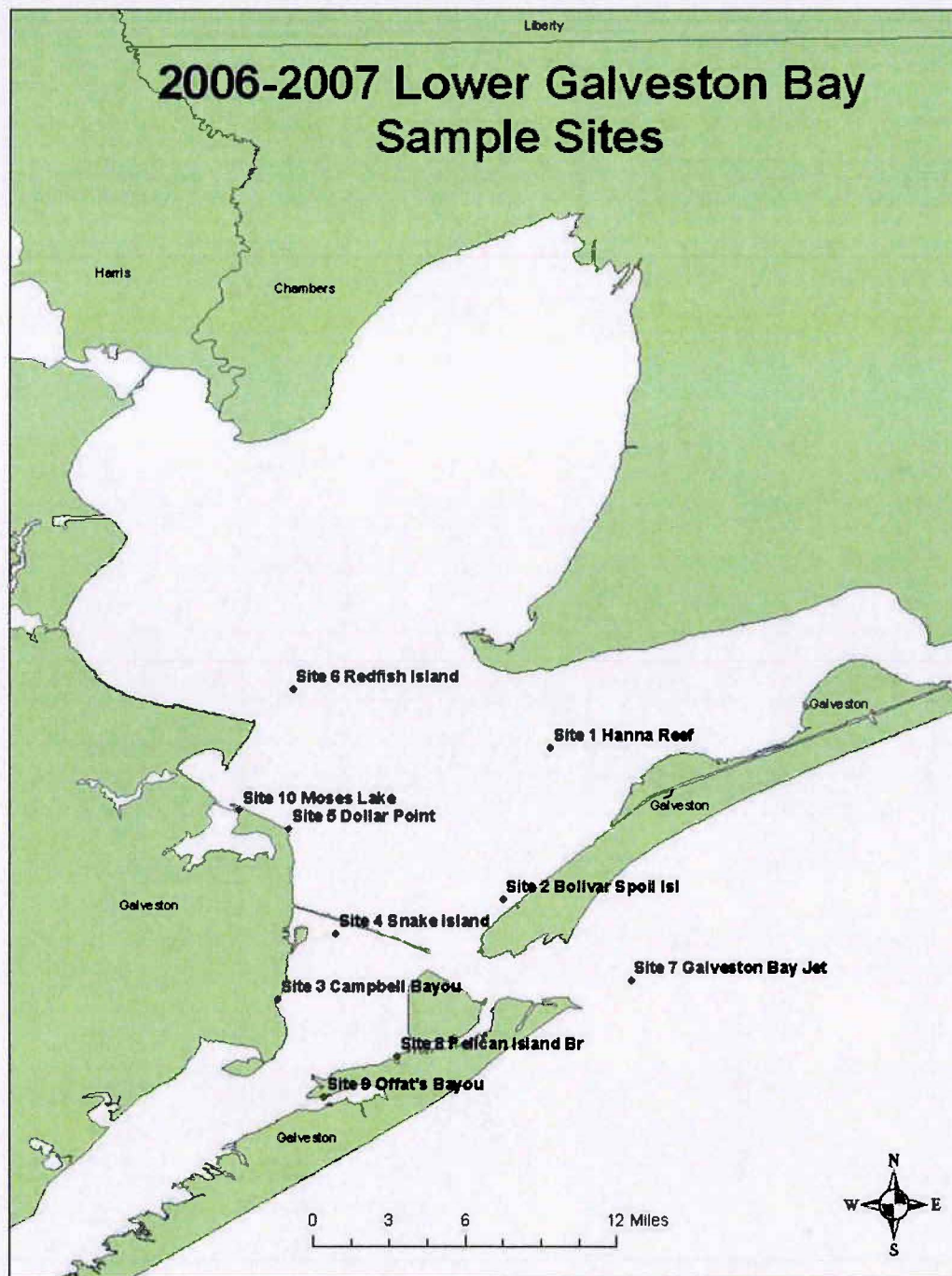


EXHIBIT XXXVII

Table 3. Toxicity Equivalency Factors (TEFs) for PCDDs/PCDFs

Item#	PCDD/PCDF Congener	Texas TEF [11]	WHO ₉₈ TEF [11]	WHO ₀₅ TEF [19]
1	2,3,7,8-TCDD	1	1	1
2	1,2,3,7,8-PeCDD	0.5	1	1
3	1,2,3,4,7,8-HxCDD	0.1	0.1	0.1
4	1,2,3,6,7,8-HxCDD	0.1	0.1	0.1
5	1,2,3,7,8,9-HxCDD	0.1	0.1	0.1
6	1,2,3,4,6,7,8-HpCDD		0.01	0.01
7	OCDD		0.0001	0.0003
8	2,3,7,8-TCDF	0.1	0.1	0.1
9	1,2,3,7,8-PeCDF	0.05	0.05	0.03
10	2,3,4,7,8-PeCDF	0.5	0.5	0.3
11	1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
12	1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
13	1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
14	2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
15	1,2,3,4,6,7,8-HpCDF		0.01	0.01
16	1,2,3,4,7,8,9-HpCDF		0.01	0.01
17	OCDF		0.0001	0.0003

EXHIBIT XXXVIII

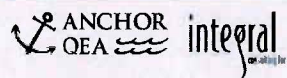
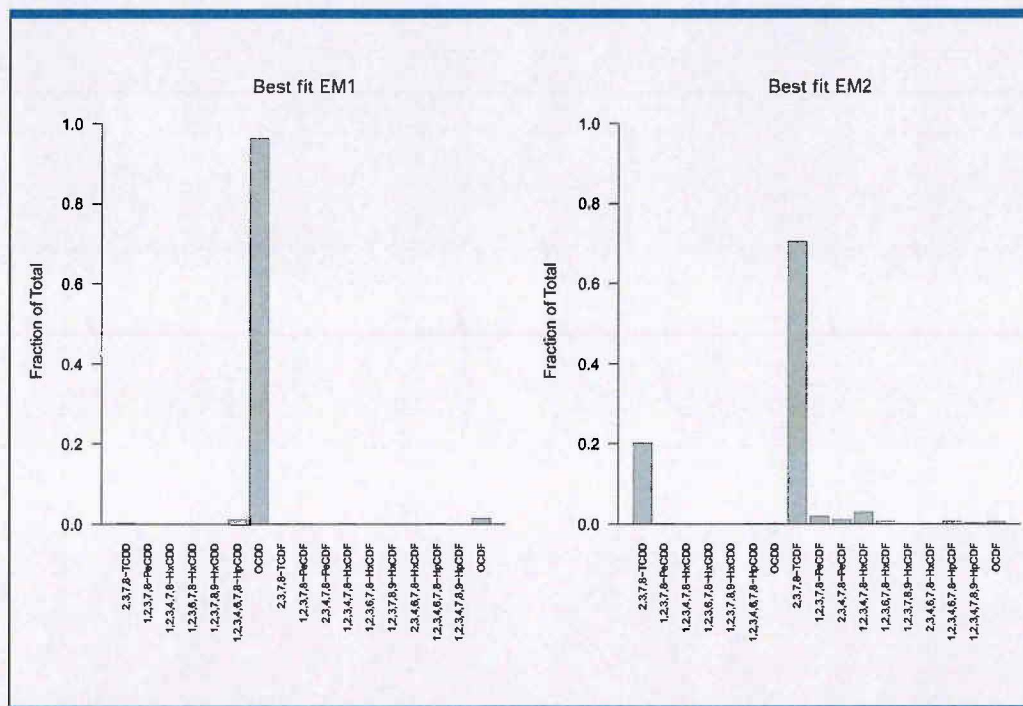


Figure 6-26
 Patterns of Dioxin and Furan Congeners in the End Members of the Best Fit Unmixing Model
 SJRWP Preliminary Site Characterization Report
 SJRWP Superfund/MIMC and IPC

Figure 6-20a
Clam and Sediment Chemistry for Transect 1
Preliminary Site Characterization Report
SIRWP Superfund/MIMC and IPC

EXHIBIT XXXX

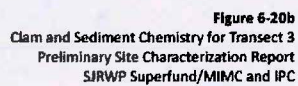
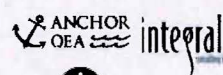
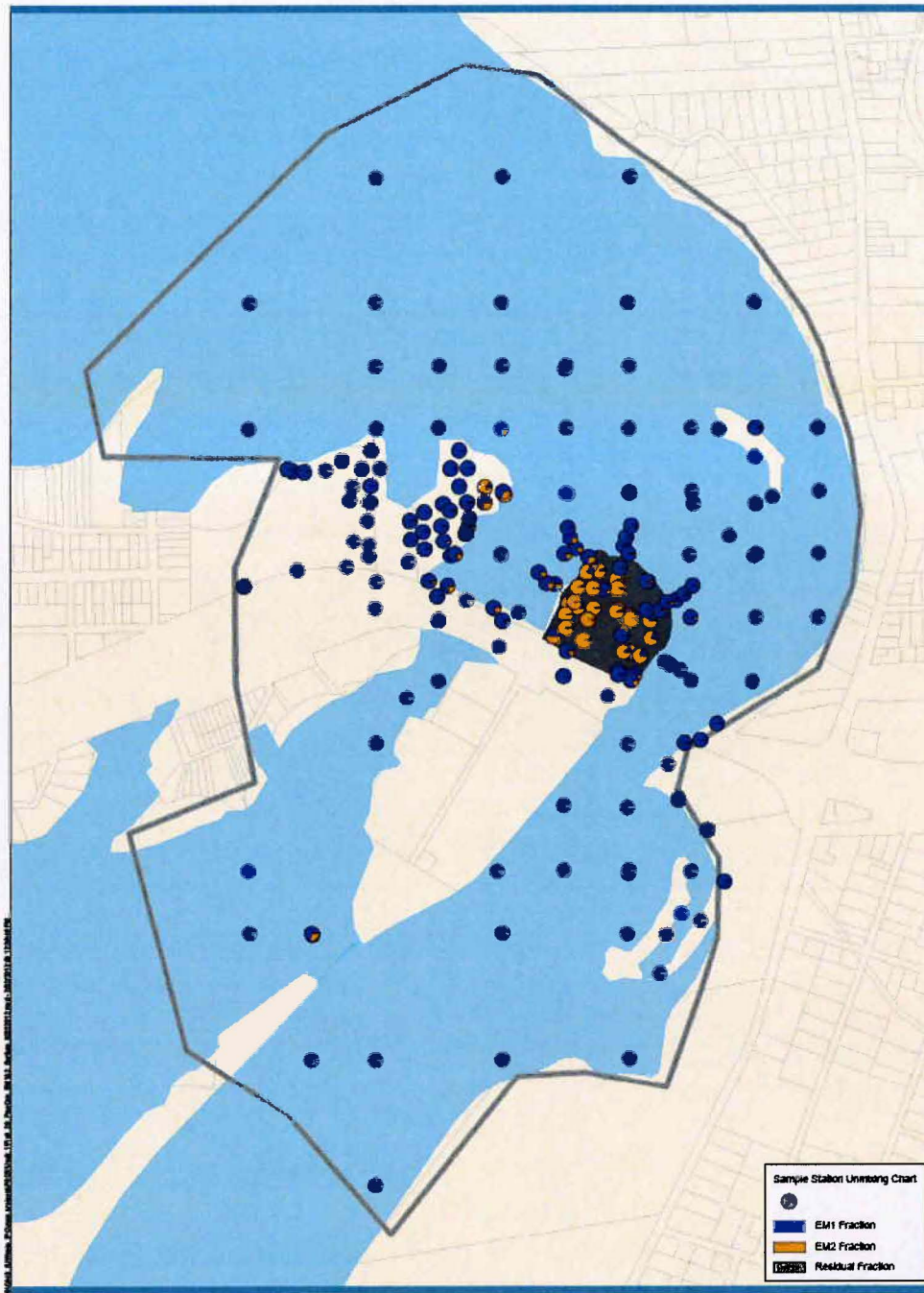


EXHIBIT XXXXI

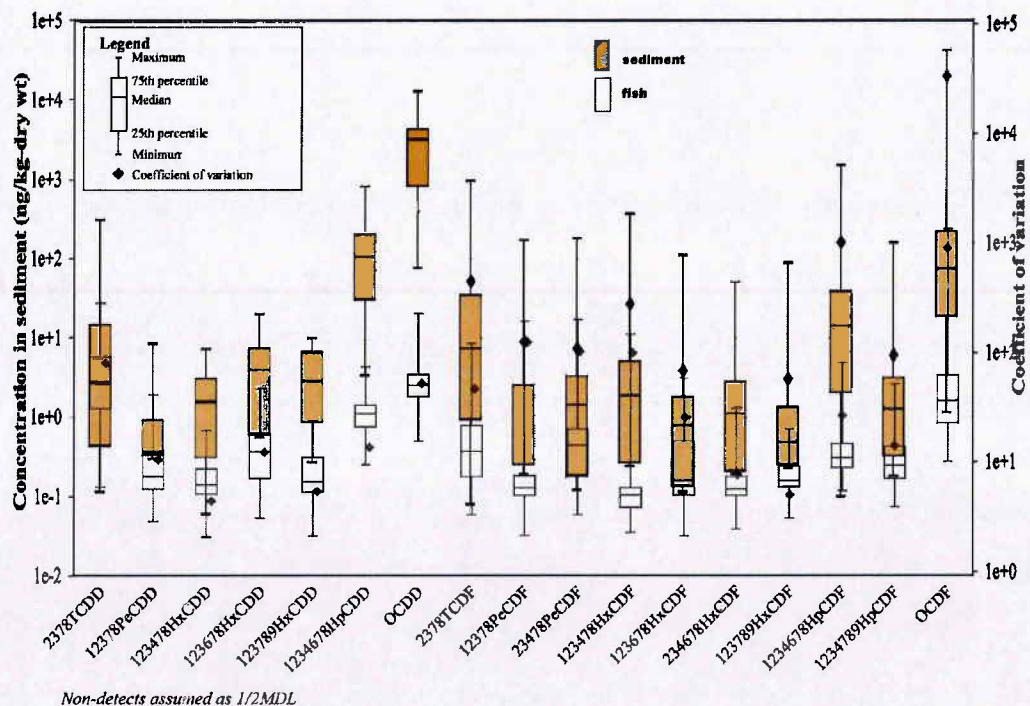


Area Within the Original (1966) Perimeter of the North Impoundments
USFWS's Preliminary Site Perimeter
Parcel Boundary

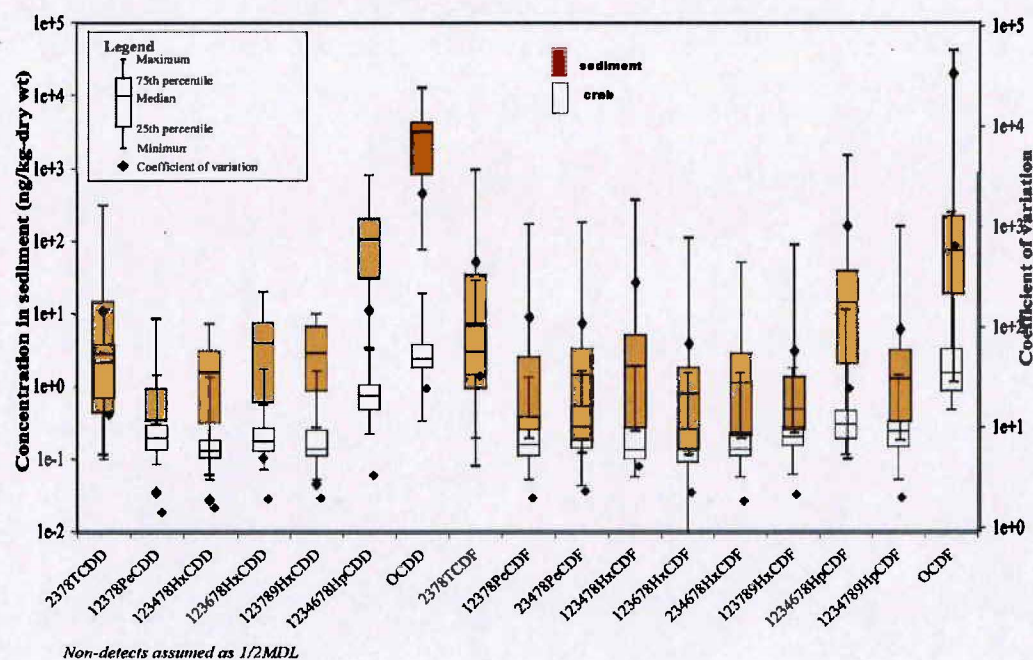
Figure 6-29
Fractional Contributions of EM1 and EM2
in Each Surface Soil and Sediment Sample
Within the Preliminary Site Perimeter
SIRWP Preliminary Site Characterization Report
SIRWP Superfund/MIMC and IPC

EXHIBIT XXXXII

A



B



RONALD L. SASS

TITLE: Professor of Biology, Chemistry, and Education, Emeritus

ADDRESS: 1834 Norfolk Street
Houston, TX 77098
Office (713)-417-3342
Home (713)-666-6538
e-mail sass@rice.edu

EDUCATION: University of Southern California, Ph.D. (Chemistry), 1957.
Augustana College, Rock Island, B.A. (Chemistry), 1954.

CURRENT POSITION Harry C and Olga K. Wiess Professor Emeritus of Natural Sciences, Rice University
2003-date
Consultant and Biogeochemical Expert Witness on Environmental Matter, 2006-date
Fellow in Climate Change, James A. Baker Institute for Public Policy, 2003-date

EXPERIENCE: Chair of Ecology and Evolutionary Biology, *Rice University* 1990-2003
Professor of Biology, Chemistry, and Education, *Rice University*, 1993-2003.
Visiting Professor, Nanjing Agricultural University, Nanjing, China, 2000.
Adjunct Professor, *University of New Hampshire*, 1999-present
Acting Chair of the Department of Education, *Rice University*, 1995-96.
Visiting Research Scientist, *NASA*, Langley, VA 1988-1989.
Chairman of Biology Department, *Rice University*, 1981-1987.
Adjunct Professor of Medicine, *Baylor College of Medicine*, 1977-present.
Professor of Biology and Chemistry, *Rice University*, 1975-1993.
Adjunct Professor of Biophysics, *Baylor College of Medicine*, 1974-1977.
Adjunct Professor of Biochemistry, *Baylor College of Medicine*, 1969-present.
Master, Hanszen College, *Rice University*, 1964 and 1966-1968.
Professor of Chemistry, *Rice University*, 1966-1975.
Visiting Professor of Theoretical Chemistry, *Cambridge University*, England, 1965.
Associate Professor of Chemistry, *Rice University*, 1962-1966.
Assistant Professor of Chemistry, *Rice University*, 1958-1962.
Research Fellow, *Atomic Energy Commission, Brookhaven National Laboratory*, Long Island, New York, 1957-1958.
Predoctoral Fellow, *National Science Foundation*, University of Southern California, 1954-1957.
Chemist, *United States Army, Rock Island Arsenal*, 1951-1954.

PROFESSIONAL ACTIVITIES

RESEARCH: Work was conducted in the Wetland Center for Biogeochemical Research at Rice University in which I was Director. Since 1988 this group has been studying the generation of biogenic atmospheric trace gases and the biological processes in waterlogged plant-soil environments leading to their formation. These gases, principally methane and nitrous oxide are important contributors to global climate change and major components of the chemical system responsible for stratospheric ozone depletion. Research originally focused on projects sponsored by the National Aeronautics and Space Administration in the tundra and boreal forest wetlands of Northern Canada and Alaska. Later work was in process studies of methane

production and mitigation strategies for methane gas emissions from rice paddies and natural wetlands, the source of nearly half of all methane gas emitted annually to the global atmosphere.

Under the sponsorship of the US Department of Agriculture and the Ministry of Agriculture of the People's Republic of China Sass traveled extensively in China to develop a cooperative effort between our laboratory and scientists in China for the study of gas emissions from Chinese and Indian rice paddies. This work began in May 1993 and culminated in a joint research program with the National Agricultural University at Nanjing the Chinese Academy of Science Atmospheric Sciences Laboratory and the University of New Hampshire.

More recently Sass initiated a study of science policy issues related to global, regional, and local climate change. The first project is to consider various facets of the urban heat island effect in Houston, Texas. This work is sponsored jointly in the Rice University Center for the Study of the Environment and Culture and the James Baker Institute of Public Policy.

INTERNATIONAL ACTIVITIES

Convenor, *International Global Atmospheric Chemistry Program* Committee on Trace Gas Exchange in Rice Paddies (RICE).

Committee members are scientific experts on atmospheric chemistry from the United States, Germany, Australia, Philippines, China, India, Thailand, and Japan. This committee is a part of the program in International Global Atmospheric Chemistry (IGAC) of the International Geosphere Biosphere Program (IGBP). The IGBP is part of the International Committee of Scientific Unions with the United States represented by the National Academy of Science. As part of this committee's activities I am an editor for a book published by the Japanese National Institute of Agro-Environmental Sciences, which is the "Proceedings of CH₄ and N₂O Workshop" held in March, 1992 at Tsukuba, Japan.

Member AGU Committee on Global Environmental Change. The purpose of this committee is to foster global environmental change science, to assure a home in AGU for all involved disciplines and individuals and, to provide scientific background for policy decisions. Global environmental change is meant to include large-scale chemical, biological, geological, and physical perturbations of the Earth's atmosphere, oceans, land surfaces, and hydrologic cycle, with special attention to time scales of decades to centuries and to human-caused perturbations.

Consultant Embrapa Meio Ambiente (Embrapa Environment). Government of Brazil. Conduct workshops, train scientists, and set up experimental system to measure trace gas emissions from Brazilian irrigated rice fields.

Consultant Advisor on Graduate Programs, The Joint Graduate School of Energy and Environment King Mongkut's University of Technology, Bangkok, Thailand

Member, Scientific Organization Committee, Workshop on GHG Emissions from Rice Fields in Asia, Chinese Academy of Science Soil Science Institute, Nanjing, China,

Consultant *Environmental Protection Agency* on Global Climate Change Issues in Agriculture. Activities I have participated in for the EPA have included workshops on various aspects of trace gas emissions, contributions to publications on atmospheric trace gases and mitigation of these gases from agricultural sources. I also serve as part of the oversight committee to monitor the EPA's program in the Philippines on the effects of increased carbon dioxide and ultraviolet radiation on agricultural crops in Asia.

Consultant *United Nations Development Program*. As a member of the External Advisory Committee to the International Rice Research Institute, I monitor the inter-regional research program on methane emission from rice fields in China, India, Indonesia, Philippines, and Thailand.

Lead Author *Organisation for Economic Co-operation and Development*. Co-authored the IPPC Guidelines on National Greenhouse Gas Inventories: Methane Emissions from Rice Cultivation (Reference Manual and Workbook). Also represented the OECD as an expert at the Twelfth Session of the IPCC in Mexico City, 1996.

Member, *National Science Teachers Association* Facilities Task Force. This committee addresses various questions of school science laboratory design and safety. It also keeps track of various regulations relating to laboratory use by students and helps teachers to be aware of them. The committee also publishes recommended designs for laboratory renovation and construction.

EDUCATIONAL ACTIVITIES

Co-director, Rice University Center for Education, 1988-date
The Center for Education at Rice University was established in 1988 as the administrative umbrella for a number of projects in school improvement in pre-kindergarten through twelfth grade.

The mission of the Center is to improve the education of children at all grade levels by identifying, fostering, and coordinating individual projects to improve teaching and learning in pre-college environments in ways that cut across their usual isolation from each other.

Over the past several years, the Center Directors have developed several successful and ongoing programs in science, mathematics, writing, Asian and multicultural studies, early children's literacy, and in the relationships between Latino students, their families, and schools. These programs operate primarily in Houston and in some surrounding districts.

OTHER

Minority Honors Pre-Med Academy Co-Director, 1988-1998.

**EDUCATIONAL
ACTIVITIES**

College Board, Science Advisory Committee, Member 1989-1994.
Educational Testing Service, Chemistry Achievement Test Committee, 1988-1994
Academy of Science and Technology, Conroe, TX. Member Academy Advisory
Council, 1988-1992.
National Center for Atmospheric Research, Education Effort Committee, 1988-date
Baylor College of Medicine, "Minority Research Apprentice Programs", Advisor, 1985-
1987
Houston High School for the Health Professions, Science Curriculum Consultant, 1985-
date
Fund for Improvement of Post-secondary Education, Consultant for the Life Sciences
Program, 1984, 1985
National Science Foundation Program to Train Master Teachers in Secondary Science
Education, Mentor, 1983-1988
Conroe Texas Independent School District, Consultant, 1984-date.
Houston Mathematics and Science Improvement Consortium, Director, 1984, 1985.

HONORS:

Rice University Gold Medal, 2007
Award Certificate from IPPC for the Nobel Peace Prize, 2007
The Texas Hall of Fame for Science, Mathematics and Technology, 2002
Meritorious Service Award, 2001, Association of Rice Alumni
Piper Professor for 1999, Piper Foundation, San Antonio, Texas
Citation for Excellence in Refereeing by the editors of the American Geophysical Union
journals. 1998.
National Research Council Senior Research Fellow (NASA), 1988.
The Rice University Honor Certificate for Teaching, 1985.
The George R. Brown Prize for Superior Teaching, 1981.
The Rice University Student Association Mentor Recognition Award, 1976.
The Rice University Award of Highest Merit, 1972.
The George R. Brown Prize for Excellence in Teaching, 1967, 1969, 1970.
Salgo-Noren Distinguished Professor Award, 1966.
Guggenheim Foundation Fellowship (Cambridge University), 1965.
Senior Class Teaching Award, 1964.
Atomic Energy Commission Postdoctoral Fellowship, 1957-1958.
Sigma Xi, 1957.
Phi Lambda Upsilon, 1955.
Phi Beta Kappa, 1954.

**PROFESSIONAL
SOCIETIES:**

American Geophysical Union
National Science Teachers Association

RECENT PRESENTATIONS, WORKSHOPS AND OTHER ACTIVITIES (only from 1993-date):

- "Process study of methane emission from rice paddies, " Jiangsu Academy of Agricultural
Sciences, Nanjing, China, May 17, 1993
- "A four year study of methane emission and production in Texas rice fields", Agro
Environmental Protection Institute, Ministry of Agriculture, Tianjin, China, May 21, 1993.
- Invited keynote address, International Symposium on Climate Change, Natural Disasters and
Agricultural Strategies, Beijing Agricultural University, Beijing, China, May 26, 1993.

"Rice Cultivation and Trace Gas Exchange" (invited), Global Atmospheric Biospheric Chemistry: The first IGAC Scientific Conference, Eilat, Israel, April 18-22, 1993, with H. U. Neue.

"Options for Reducing Methane Emissions from Rice Cultivation" (invited), White House Conference on Global Climate Change, Washington D.C. June 10-11, 1993.

STELLA Model Demonstrations, Update (invited), Spring Meeting of the Cooperative University-Based Program in Earth System Science Education, Langley Research Center, Hampton, VA, June 22-23, 1993.

Methane Emission from Rice Paddy: IGAC Foci (keynote address), All Asian Workshop-Cum-Training Course on Methane Emission Studies, National Physical Laboratory, New Delhi, India, September 20-24, 1993.

"Methane Emission: Five Year Study at Rice University" (Invited), All Asian Workshop-Cum-Training Course on Methane Emission Studies, National Physical Laboratory, New Delhi, India, September 20-24, 1993.

IGAC Approach to Measurement Procedures (Invited), Federation of Asian Scientific Academies and Societies Seminar on Global Environment Chemistry, New Delhi, India, Sept. 27-Oct. 1, 1993.

"Tracegas Exchange with the Biosphere-I " (Invited), Federation of Asian Scientific Academies and Societies Seminar on Global Environment Chemistry, New Delhi, India, Sept. 27-Oct. 1, 1993.

"Methane Emission: Five Year Study at Rice University " (Invited), Regional Research Laboratory, Bhubaneswar, India, October 2, 1993.

"Methane Emission from Rice Fields in the United States" (Invited) International Symposium on Climate Change and Rice, International Rice Research Institute, Los Baños, Philippines, March 14-16, 1994.

Member, External Advisory Committee, United Nations Development Program, Interregional Research Program on Methane Emission from Rice Fields, Los Baños, Philippines, March 17-18, 1994.

Rice Cultivation and Trace Gas Exchange, CH₄ and N₂O Workshop, National Institute for Agro-Ecological Sciences, Tsukuba, Japan, March 23-25, 1994.

International Global Atmospheric Chemistry-Global Change & Terrestrial Ecosystems Task Team; Inaugural Meeting, Oxford UK, 8-9 December, 1994.

"A Multi-year Study of Methane Emissions from Texas Rice Fields, " Engineering Faculty, Tulane University, New Orleans, LA, March 10, 1995

"Methane Emission from Rice Paddies; A Process Study " (invited), International Symposium on Soil-Source and Sink of Greenhouse Gases, Institute of Soil Sciences (CAS), Nanjing, China, September 14-30, 1995.

Opportunities for Mitigation of CH₄ Emissions from Agricultural Sources (invited IPCC Symposium), American Society of Agronomy Annual Meeting, St. Louis, MO, October 29-Nov 3, 1995.

Convenor, The NASA Workshop on Regional Assessment of Tracegas Emissions from Rice Fields of China, Rice University, November 7-9, 1995.

Member, External Advisory Committee, United Nations Development Program, Interregional Research Program on Methane Emission from Rice Fields, Bangkok, Thailand, November 19-25, 1995.

"The China Experience." Lecture Series, Rice University Homecoming December 1-3, 1995.

"Climate and Change." Rice University Summit of the Minds, February 3, 1996

"Global Change," Toward the 21st Century, Topics in Contemporary Science, Rice University, April 8, 1996.

"Who Will Feed Asia?" Rice University Alumni College, April 26-28, 1996.

Participant, IPCC/OECD Meeting of Experts on Emission Factors for Methane from Wetland Rice Cultivation, Bangkok, Thailand, April 30-May 2, 1996.

"Agricultural Practices and Other Factors Influencing Methane Emissions from Rice Fields" (Invited), IPCC/OECD Meeting of Experts on Emission Factors for Methane from Wetland Rice Cultivation, Bangkok, Thailand, April 30-May 2, 1996.

International Geosphere Biosphere Program Wetlands Workshop on Classification, University of California at Santa Barbara, May 16-20, 1996.

Convenor, The NASA Workshop on Regional Assessment of Tracegas Emissions from Rice Fields of China, Beijing, China, June 5-7, 1996.

Participant, Intergovernmental Panel on Climate Change Working Group I, Sixth Session, Mexico City, Mexico, September 10, 1996.

"Global Change: Are We Warming Up?", Rice University Families Weekend, October 4-5, 1996.

"Wetlands and Global Climate Change," Wetland Biogeochemistry Institute, Louisiana State University, Baton Rouge, October 17, 1996.

"Mechanisms of Methane Emission from Flooded Agricultural Systems: A Modeling Study." Tulane University, New Orleans, April 4, 1997.

Rice Environmental Conference 1997, February 1, 1997 Panel Participant: The Scope of Technology in Environmental Protection

IGAC Science Advisory Council Meeting, Toronto, Ont., Canada, May 16-19, 1997.

IPCC Scientific Steering Committee, Expert Group on Methods for the Assessment of Country Greenhouse Gas Inventory Quality, National Institute of Public Health and the Environment, Bilthoven, Netherlands, November 5-7, 1997.

"Mechanisms of Methane Emission from Flooded Rice Fields: A Modelling Study. " Max-Planck-Institut für Terrestrische Mikrobiologie, Marburg, Germany, November 10, 1997

"Mechanisms of Methane Emission from Flooded Rice Fields: A Modelling Study. " UFZ-Centre for Environmental Research, Department of Soil Sciences, Bad Lauchstaedt, Germany, November 13, 1997.

TRAGNET Working Group to Synthesize Trace Gas Research in Managed and Natural Ecosystems. National Center for Ecological Analysis and Synthesis, Santa Barbara, California, December 2-6, 1997.

"A semi-empirical model of methane emission from irrigated rice fields." (Invited) Workshop of the Interregional Research Program on Methane Emission from Rice Fields in Beijing China, August 10-15, 1998 sponsored by the United Nations Development Programme Global Environmental Facility and the International Rice Research Institute.

"Exchange of methane and other trace gases from rice fields: a model system for wetland emission modeling." (Invited) The Ninth Symposium of the IAMAS Commission on Atmospheric Chemistry & Global Pollution (CACGP) and Fifth Scientific Conference on the International Global Atmospheric Chemistry Project (IGAC), Seattle, Washington, 19-25 August 1998.

"A semi-empirical model of methane emission from irrigated rice fields." The Ninth Symposium of the IAMAS Commission on Atmospheric Chemistry & Global Pollution (CACGP) and Fifth Scientific Conference on the International Global Atmospheric Chemistry Project (IGAC), Seattle, Washington, 19-25 August 1998.

"Methane emissions from rice fields: Effect of rice cultivars and plant height." The Ninth Symposium of the IAMAS Commission on Atmospheric Chemistry & Global Pollution (CACGP) and Fifth Scientific Conference on the International Global Atmospheric Chemistry Project (IGAC), Seattle, Washington, 19-25 August 1998.

"Global Warming and Climate Change." The Association of Rice Alumni, Alumni College, November 7, 1998. Washington, D.C.

"Agricultural Sources of Methane and Nitrous Oxide: Methane from Rice Agriculture" Invited background paper. IPCC/OECD workshop, "Good Practice in Inventory Preparation: Agricultural Sources of Methane and Nitrous Oxide." Wageningen Agricultural University (The Netherlands). February 24-26, 1999.

"Modeling Methane Emissions from Chinese Rice Paddies." Agro-Meteorological Research Center of Chinese Academy of Meteorological Sciences, Beijing, China. May 24, 1999.

"Regional and Country Level Assessment of Methane from Rice Paddies." Institute of Remote Sensing, Chinese Academy of Sciences, Beijing China, May 25, 1999.

"Factors Affecting Methane Emissions from Rice Paddies: Modeling and Remote Sensing." Institute of Natural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing, China, May 26, 1999.

- "A GIS Based System for Estimating Methane Emissions from Rice Paddies." Chinese Ecological Research Network, Chinese Academy of Sciences, Beijing, China, May 27, 1999.
- "Modeling Methane Emissions from Chinese Rice Paddies." Nanjing Agricultural University, Nanjing, China, May 31, 1999.
- "A GIS Based System for Estimating Methane Emissions from Rice Paddies." Chinese Ecological Research Network, Institute of Agricultural Modernization and Remote Sensing, Changsha, China, June 7, 1999.
- "Modeling Methane Emissions from Chinese Rice Paddies." Guangxi Academy of Agricultural Science, Nanning, China, June 9, 1999.
- "A GIS Based System for Estimating Methane Emissions from Rice Paddies." Chinese Ecological Research Network Tropical Forest Station at Xi-shuang-ban-na, China, June 14, 1999.
- "Monitoramento e mitigação da emissão de metano pela cultura do arroz." Invited talk to the First Brazilian Irrigated Rice Congress and the XXIII Irrigated Rice Cultivation Meeting, Pelotas, RS, Brazil, August 4, 1999.
- "Modeling and Remote Sensing of Methane Emissions from Rice Paddies". Nanjing Meteorological Institute, Nanjing, China, March 25, 2000
- "Global Ecosystem Dynamics", A short course, Nanjing Agricultural University, Nanjing, China, March 19-24, 2000
- Session convenor: Biogeochemistry of C and N in Soils I. American Geophysical Union Spring Meeting, May 30-June 3, 2000, Washington, D. C., with S. Frolking
- Session convenor: Biogeochemistry of C and N in Soils II Posters, American Geophysical Union Spring Meeting, May 30-June 3, 2000, Washington, D. C., with S. Frolking
- "A Process Model of Methane Production, Oxidation and Transport in Paddy Rice Ecosystems" Invited talk, American Geophysical Union Spring Meeting, May 30-June 3, 2000, Washington, D. C., with Li, C. Zhang, Y. , Huang, Y., and Butterbach-Bahl, K
- "Spatial Variability in Methane Emissions from Rice Fields", Department of Earth, Oceans, and Space, University of New Hampshire, August 16, 2000
- "Spatial Variability in Methane Emissions from Rice Fields", Departments of Ecology & Evolutionary Biology and Earth Systems, University of California at Irvine, Nov. 3, 2000
- "Seasonal and Spatial Variability of Methyl Halide Emissions from Rice Paddies near Houston, Texas" Fall Meeting of American Geophysical Union, December 15-19, 2000, San Francisco, California. With Redeker, K. , Andrews, J., Fisher F. and. Cicerone, R. J.
- "Spatial and temporal variability in methane emissions from rice paddies: Implications for assessing regional methane budgets", Workshop on GHG Emissions from Rice Fields in Asia, Chinese Academy of Science Soil Science Laboratory, Nanjing, China, Feb. 26, 2001.

- "Spatial Variability in Methane Emissions from Rice Fields", Nanjing Agricultural University, Nanjing, China, March 1, 2001.
- "Spatial Variability in Methane Emissions from Rice Fields", Chinese Academy of Science, Atmospheric Science Laboratory, Beijing, China, March 8, 2001.
- "Spatial Variability in Methane Emissions from Rice Fields", The Joint Graduate School of Energy and Environment King Mongkut's University of Technology, Bangkok, Thailand, September 26, 2001.
- "Remote Sensing of Methane Emissions from Rice Fields", The Thailand Research Fund, Program on Greenhouse Gas Emissions Assessment. Bangkok, Thailand, September 28, 2001
- "Five lectures on Ecology and Global Change" Presented during an ecotourism trip on the Peruvian Amazon River. Sponsored by the Rice Alumni Association, October 20-28, 2001
- "Can you see China from Texas", Rice's Best: Winners of Rice University's Teaching Awards 1999-2000, Rice School of Continuing Studies, November 19, 2001
- "Global Measurement Standardization of Methane Emissions from Irrigated Rice Cultivation", Embrapa Meio Ambiente (Embrapa Environment), Jaguaruna, SP, Brazil, January 29, 2002.
- "An Extensive Survey of Gaseous Emissions from Rice Paddy Agriculture", with Redeker, K R, Meinardi, S, Blake, D, and Cicerone, R. American Geophysical Union, Spring meeting, Washington, DC., May 28-31, 2002
- NACP Methane Workshop, Breakout session on process studies in atmospheric methane emissions, University of New Hampshire, September 10-12, 2002.
- "Mitigation of Methane Emissions from Rice Fields", Non-CO2 Network Project on Agricultural Greenhouse Gas Mitigation, Environmental Protection Agency, Washington, DC, December 2-3, 2002.
- "Human Response to the Subject of Global Warming" Conference on climate change at the Shell Center for Sustainability, Baker Institute, Houston, TX Sept. 14, 2004.
- "Texas Coastal Marshes and Potential impact of Gulf of Mexico Oil Spills", U.S. Offshore Oil Exploration: Managing Risks to Move Forward, Baker Institute, Houston, TX, Feb. 11, 2011
- "Gulf of Mexico Currents and Fate of Spilled Oil", International Association of Drilling Contractors, Port of Spain, Trinidad, May 12-13, 2011.
- "Gulf of Mexico Currents and the Proposed Lone Star National Recreational Area". Houston Sierra Club, Houston, TX January 10, 2013.
- "2012, The Year Climate Change Became Real". Atmosphere and Waste Management Association, Houston, TX, April 2, 2013.

PUBLICATIONS:

Books:

CH₄ and N₂O Global Emissions and Controls from Rice Fields and Other Agricultural and Industrial Sources, NIAES Japan, 1994, Editors K. Minami, A. Mosier and R. L. Sass.

Journal Articles and Book Chapters:

1. Sass, R.L. and Donohue, J. (1957) The Unit Cell and Space Group of HCN Tetramer. **Acta Cryst.**, 10:375.
2. Sass, R.L., Vidale, R. and Donohue, J. (1957) Interatomic Distances and Thermal Anisotropy in Sodium Nitrate and Calcite. **Acta Cryst.**, 10:567-570.
3. Sass, R.L. and Donohue, J. (1958) The Crystal Structure of S₄N₄H₄. **Acta Cryst.**, 11:497-504.
4. Sass, R.L. (1960) A Neutron Diffraction Study on the Crystal Structure of Sulfamic Acid. **Acta Cryst.**, 13:320-324.
5. Hastings, J., Corliss, L., Elliott, N. and Sass, R.L. (1961) Magnetic Structure of Chromium Selenide. **Phy. Rev.**, 122:1402-1406.
6. Church, J.F. and Sass, R.L. (1962) A Study of the Crystal Structure of Trimethyl cis-Cyclopropane-1,2,3-tricarboxylate. **Chem. Ind.** 1574.
7. Sass, R.L. and Scheuerman, R.F. (1962) The Crystal Structure of Sodium Bicarbonate. **Acta Cryst.**, 15:77-81.
8. Strieter, F.J., Templeton, D.H., Scheuerman, R.F. and Sass, R.L. (1962) The Crystal Structure of Propionic Acid. **Acta Cryst.**, 15:1233-1239.
9. Scheuerman, R. F. and Sass, R.L. (1962) The Structure of Valeric Acid. **Acta Cryst.**, 15:1244--1247.
10. Sass, R.L. and Ratner, L. (1963) Crystal Symmetry of the Dimer of Cyclobutene-1,2-dicarboxylic Acid Dimethyl Ester. **Acta Cryst.**, 16:433.
11. Higgs, M.A. and Sass, R.L. (1963) The Crystal Structure of Acrylic Acid. **Acta Cryst.**, 16:657-661.
12. Brackett, E.B., Brackett, T.E. and Sass, R.L. (1963) The Crystal Structure of Barium Chloride, Barium Bromide and Barium Iodide. **J Phys. Chem.**, 67:2132-2135.
13. Sass, R.L., Brackett, T.E. and Brackett, E.B. (1963) The Crystal Structure of Strontium Bromide. **J. Phys. Chem.**, 67:2862-2863.
14. Sass, R.L., Brackett, E.B. and Brackett, T.E. (1963) The Crystal Structure of Lead Chloride. **J. Phys. Chem.**, 67:2863.
15. Brackett, E.B., Brackett, T.E. and Sass, R.L. (1963) The Crystal Structure of Calcium Bromide. **J. Nucl. and Inorg. Chem.**, 25:1295-1296.
16. Bugg, C.E., Lawson, J.B. and Sass, R.L. (1964) The Crystal Symmetry of Several Diazonium Salts. **Acta Cryst.**, 17:767-768.

17. Dyke, M. and Sass, R.L. (1964) The Crystal Structure of Strontium Bromide Monohydrate. **J. Phys. Chem.**, 68:3259-3262.
18. Bugg, C.E., Desiderato, R. and Sass, R.L. (1964) An X-Ray Diffraction Study of Nonplanar Carbanion Structures. **J. Am Chem. Soc.**, 86:3157-3158.
19. Roth, W.R., Bang, W.B., Geobel, P., Sass, R.L., Turner, R.B. and Yu, A.P. (1964) On the Question of Homoconjugation of cis,cis,cis-1,4,7- Cyclononatriene. **J. Am. Chem. Soc.**, 86:3178-3179.
20. Desiderato, R. and Sass, R.L. (1965) The Crystal Structure of Ammonium Tricyanomethide, $\text{NH}_4\text{C}(\text{CN})_3$. **Acta Cryst.**, 18:1-4.
21. Bugg, C.E. and Sass, R.L. (1965) The Crystal Structure of Pyridinium Dicyanomethylide, $\text{C}_8\text{H}_5\text{N}_3$. **Acta Cryst.**, 18:591-594.
22. Kilpatrick, J.E. and Sass, R.L. (1965) Structure of the X^{P} Matrices in the Simple Harmonic Oscillator Representation. **J. Chem. Phys.**, 42:2581-2586.
23. Sass, R.L. and Bugg, C.E. (1967) The Crystal Structure of Potassium p-Nitrophenyldicyanomethide. **Acta Cryst.**, 23:282-288.
24. Desiderato, R. and Sass, R.L. (1967) The Crystal Structure of cis-2- Butene Episulfone. **Acta Cryst.**, 23:430-433.
25. Dyke, M. and Sass, R.L. (1968) The Crystal Structure of Dipotassium Tetranitroethide. **J. Chem. Phys.**, 72:266-268.
26. Kronfeld, L.R. and Sass, R.L. (1968) The Crystal Structure of Dibenzothiophene Sulfone. **Acta Cryst.**, B24:981-982.
27. Herdktlotz, J.K. and Sass, R.L. (1969) The Crystal Structure of 4-Methyl- thiomorpholine-1,1-dioxide. **Acta Cryst.**, B25:1614-1620.
28. Edmonds, J., Herdktlotz, J.K. and Sass, R.L. (1970) The Crystal Structure of Ammonium 1,1,2,6,7,7-Hexacyanoheptatrienide. **Acta Cryst.**, B26:1355-1362.
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